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Preliminary Review of Psychophysiological Technologies to Support Multimodal UAV Interface Design

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PWGSC Contract Number:
w7711-098148/001/TOR Call-up: 8148-02

Contract Scientific Authority
Robert Arrabito, Defence Scientist

Defence R&D Canada
Contract Report
DRDC Toronto CR 2010-050
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Canada

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Abstract

To improve operational effectiveness for the Canadian Forces (CF), the Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System (JUSTAS) project is acquiring a medium-altitude, long-endurance (MALE) uninhabited aerial vehicle (UAV). In support of the JUSTAS project, Defence Research and Development Canada (DRDC) – Toronto is investigating strategies for managing massive information exchange among UAV operators. One strategy to is to develop intelligent adaptive interfaces (IAI) that dynamically manage information display and control characteristics based on operator mental state or workload through assessing operators' physiological indexes by using Electroencephalography (EEG) and Electrocardiography (ECG) technologies. This report presents research findings in evaluating EEG and ECG technologies, lessons learned on the use of these technologies, and their associated implications in experimental research. Suggestions are made for the development of a research program for a study to enhance the IAI design. Recommendations are also provided for defining future requirements in support of the JUSTAS project.

Résumé

En vue d'améliorer l'efficacité opérationnelle des Forces canadiennes (FC), l'acquisition d'un engin télépiloté (UAV) moyenne altitude et longue endurance (MALE) est un des volets du projet Système interarmées de surveillance et d'acquisition d'objectifs au moyen de véhicules aériens sans pilote (JUSTAS). À l'appui du projet JUSTAS, Recherche et développement pour la défense Canada (RDDC) — Toronto effectue des recherches sur des stratégies visant à gérer l'importante quantité d'information échangée entre les opérateurs d'UAV. L'une de ces stratégies consiste en la mise au point d'interfaces adaptatives intelligentes (IAI) qui gèrent l'affichage de l'information de façon dynamique et commandent les caractéristiques en fonction de l'état mental de l'opérateur ou de sa charge de travail mentale à partir de l'évaluation des indices physiologiques de l'opérateur au moyen de technologies d'électroencéphalographie (EEG) et d'électrocardiographie (ECG). Le présent rapport décrit les découvertes faites lors de l'évaluation de technologies d'EEG et d'ECG, les leçons retenues de l'utilisation de ces technologies et leurs répercussions sur la recherche expérimentale. Il comporte des suggestions relatives à l'élaboration d'un programme de recherches visant à améliorer la conception des IAI, et des recommandations en vue de cerner les exigences futures à l'appui du projet JUSTAS.

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Executive summary

Preliminary Review of Psychophysiological Technologies to Support Multimodal UAV Interface Design

Plinio Morita; Fiona Chui; Catherine Burns; DRDC Toronto CR 2010-050; Defence R&D Canada – Toronto; May 2010.

Background: Uninhabited aerial vehicles (UAVs) are remotely controlled aircraft used for a variety of civilian and military applications including command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR). To improve C4ISR capability, the Canadian Forces (CF) is acquiring a medium-altitude, long-endurance (MALE) UAV under the Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System (JUSTAS) project. In support of the JUSTAS project, Defence Research and Development Canada (DRDC) – Toronto is investigating intelligent adaptive interfaces (IAI) to manage information effectively. The aim of IAI is to dynamically change displays and control characteristics to effectively manage information, reduce operator workload, and thus maximize human-machine system performance. Psychophysiological monitoring technologies can facilitate the assessment of operator performance and present an opportunity (e.g., changes in mental workload, body temperature or heart rate) to trigger IAI functions. Electroencephalography (EEG) and electrocardiography (ECG) technologies have been used to evaluate operator mental state or workload. These technologies likely present opportunities to assess operator mental states and workload for the design of IAI. However, these technologies are not yet fully understood in terms of their potential to assess operator performance for the control of UAVs.

Results: This research compared, acquired, and evaluated several different EEG and ECG technologies. The purpose was to verify the types of measurements that could be made with the equipment. Lessons learned in setting up the equipment and using it in a research environment are provided. For each technology (EEG and ECG), three different systems were chosen and examined for their ability to measure operator performance in the context of UAV operation when using a multimodal interface. Based on an evaluation against established criteria, the B-Alert system was selected as the best EEG unit for this context and the Flexcomp Infiniti system as the best ECG unit. Performance tests were conducted for evaluating synchronization performance, unit performance and software performance. For each evaluation the focus was on initial set-up, usage and disassembly/clean-up.

Significance: Both systems can meet operator performance measurement requirements that were defined in the Statement of Work. However, the selection of one system over another may depend on the type of study being conducted and the number of participants in that study, since each system has its own limitations and complexities. If required, the two acquired systems can be integrated and used simultaneously.

Future plans: The development of a research program to enhance the design of GCS IAI will be performed based on the acquired psychophysiological technologies. The results of the study will provide recommendations to support future requirements of the JUSTAS project.

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Preliminary Review of Psychophysiological Technologies to Support Multimodal UAV Interface Design

Plinio Morita; Fiona Chui; Catherine Burns; DRDC Toronto CR 2010-050; R & D pour la défense Canada – Toronto; Mai 2010.

Introduction : Les engins télépilotés (UAV) sont des aéronefs commandés à distance qui servent à diverses applications civiles et militaires, dont le C4ISR (commandement, contrôle, communications, informatique, information, surveillance et reconnaissance). En vue d'améliorer leur capacité C4ISR, les Forces canadiennes ont décidé d'acquérir un UAV moyenne altitude et longue endurance dans le cadre du projet Système interarmées de surveillance et d'acquisition d'objectifs au moyen de véhicules aériens sans pilote (JUSTAS). À l'appui du projet JUSTAS, Recherche et développement pour la défense Canada (RDDC) - Toronto effectue des recherches sur les interfaces adaptatives intelligentes (IAI) en vue de la gestion efficace de l'information. Les IAI servent à modifier les affichages de façon dynamique et à commander les caractéristiques pour gérer efficacement l'information et réduire la charge de travail de l'opérateur et ainsi optimiser le rendement du système homme-machine. Les technologies de surveillance de l'état psycho-physiologique peuvent faciliter l'évaluation du rendement de l'opérateur et permettre l'activation de fonctions IAI (p. ex. variations de la charge de travail mentale, de la température corporelle ou du pouls). Des technologies d'électroencéphalographie (EEG) et d'électrocardiographie (ECG) ont servi à évaluer l'état mental de l'opérateur et sa charge de travail mentale. Quoique ces technologies offrent probablement l'occasion d'évaluer les états mentaux de l'opérateur et sa charge de travail mentale en vue de la conception d'IAI, le potentiel de ces technologies en ce qui à trait à l'évaluation du rendement de l'opérateur d'UAV n'est pas encore très bien compris.

Résultats: Différentes technologies d'EEG et d'ECG ont été comparées, acquises et évaluées pour tester les types de mesures qui peuvent être prises avec le matériel. Le présent rapport comporte les leçons retenues de la mise en place du matériel et de son utilisation dans un milieu de recherches. Trois systèmes différents ont été choisis pour chacune des technologies EEG et ECG, et leur capacité à mesurer le rendement d'un opérateur qui utilise une interface multimodale pour commander un UAV a été évaluée. Le système B-Alert a été choisi en tant que meilleur système EEG pour ce contexte, et le système Flexcomp Infinity a été choisi en tant que meilleur système ECG, selon des critères d'évaluation établis. Des tests de fonctionnement ont été effectués pour évaluer la synchronisation, ainsi que les performances des systèmes et des logiciels. Pour chaque évaluation, l'accent a été mis sur la mise en place initiale, la facilité d'utilisation et le désassemblage et le nettoyage.

Portée: Les deux systèmes peuvent satisfaire aux exigences relatives à la mesure du rendement de l'opérateur conformément à l'énoncé des travaux. Le choix d'un système par rapport à un autre peut toutefois dépendre du type d'étude menée et du nombre de personnes y participant, en raison des restrictions et des complexités propres à chaque système. Au besoin, les deux systèmes acquis peuvent être intégrés et être exploités simultanément.

Recherches futures : Un programme de recherche visant à améliorer la conception d'IAI pour SCS sera effectué selon les technologies psycho-physiologiques acquises. Les résultats de ces recherches apporteront des recommandations pour assister les exigences futures du projet JUSTAS.

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1 Introduction

1.1 Background

Uninhabited aerial vehicles (UAVs) are remotely controlled aircraft used for a variety of civilian and military applications including command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR). To improve C4ISR capability, the Canadian Forces (CF) is acquiring a medium-altitude, long-endurance (MALE) UAV under the Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System (JUSTAS) project.

In support of the JUSTAS project, Defence Research and Development Canada (DRDC) – Toronto is investigating Intelligent Adaptive Interfaces (IAI) to manage information effectively. The aim of IAI is to dynamically change displays and control characteristics to effectively manage information, reduce operator workload, and thus maximize human-machine system performance.

UAVs are controlled by a Ground Control Station (GCS) that facilitates ISR activities without the need of an in-craft pilot. This reduces risk, the need for on-board life support systems, weight, and fuel consumption, thereby increasing the range and possibilities of use such as long-duration surveillance in high-risk environments such as storms and conflict zones. Many of these systems contain high levels of automation, which might create opportunities to increase GCS operator capability through the monitoring of multiple UAVs. However, these systems present new challenges as well. With the pilot outside of the aircraft, one does not receive the environmental and ambient cues that an in-craft pilot would receive. This creates a need to explore the best ways of presenting information to the pilot. Multimodal displays and adaptive displays are promising options that could provide richer information and more advanced information management.

Exploring multimodal and adaptive displays requires monitoring pilot performance and state. As an example, an intelligent adaptive interface may use readings of pilot state to selectively present information to the user. Various ways of obtaining information on operator mental and physical condition include eye tracking systems, neural electroencephalography (EEG) readings, electrocardiography readings (ECG) and galvanic skin response readings (GSR). These types of readings could indicate operator state and be used as triggers to adaptively alter the presentation of information to the pilot

Psychophysiological technologies can also be useful in evaluating new interface designs when comparing them to the existing designs. Small differences in mental workload can occur while using these different systems, manifesting themselves as changes in neural activity, heart rate, and skin conductance. For example, Berka et al. (2007) describe the correlation of EEG and mental workload for vigilance and memory tasks and Stermann & Mann (1995) apply EEG for aviation performance evaluation.

In this project, several different EEG and ECG technologies were evaluated for their capability to collect information on operator physiological state. Two different systems were purchased and further evaluated within the Advanced Interface Design Lab to verify that their performance matched the manufacturer's specifications and our expectations for future projects investigating UAV ground control station designs and adaptive interfaces. In this report, equipment evaluations, lessons learned from the use of the equipment, and the potential of using this equipment in the development of intelligent adaptive interfaces for the GCS are provided.

1.2 Objective

The current report has been written by the Advanced Interface Design Lab at the University of Waterloo. Its purpose is to provide the necessary human factors expertise in the evaluation of psychophysiological technologies to be used in UAV GCS multimodal interface research and design. The suitable technologies have been identified, evaluated and acquired to support the development of the DRDC Toronto multimodal GCS interface. These technologies will be used to evaluate operator performance for different UAV GCS interface designs in order to assess the changes in mental and physical workload imposed on the operator by each specific design.

2 Project Criteria According to the Statement of Work

Specific project criteria were provided in the Statement of Work. To better understand the report and the purpose of the project, these criteria are listed below.

2.1 Preliminary Technical Review of Technologies

Perform a preliminary technical review of EEG and ECG technologies as an augmented cognition technique to facilitate multimodal perception and psychology. Items to address include, but are not limited to:

- Identify suitable products in the current market space
- Acquire available product brochures and pricing
- Provide as much information about the products as possible with the DRDC Toronto application in mind
- Suggest suitable configuration of products for DRDC Toronto project
- Where possible, arrange demonstration of products at DRDC Toronto
- Rank the top three EEG and ECG products
- Recommend the product to be evaluated

2.2 Preliminary Evaluation of Acquired Technologies

- Evaluate the demonstrable use of EEG and ECG technology in simulation and its extensibility for different research settings in the GCS
- Evaluate the demonstrable use of ECG and ECG technology in simulation and its extensibility for different research settings in the GCS
- Evaluate the integration feasibility of EEG and ECG technology with another psychophysiological technology (e.g., an eye tracking system) for the GCS interface
- Evaluate the integration feasibility of EEG technology with another two psychophysiological technologies (e.g., eye tracking and ECG systems) for the GCS interface
- Recommend the integration strategy with pros/cons
- Document all evaluations that were performed

3 Preliminary Review on Psychophysiological Technologies

In order to evaluate psychophysiological technologies to support multimodal UAV interface design, the following steps were completed:

- A preliminary technical review of electroencephalography (EEG) technologies
- A preliminary technical review of electrocardiography (ECG) technologies
- A preliminary evaluation of recommended products

The preliminary review of psychophysiological technologies focused on EEG and ECG products according to the Statement of Work.

3.1 Preliminary Technical Review of Electroencephalography (EEG) Technologies

A preliminary technical review of EEG technologies was performed according to the Statement of Work. In this section, various EEG products are discussed. Their specifications are compared against the needs of the DRDC Toronto application and one of the possible systems is recommended for purchase and further evaluation.

3.1.1 Suitable Products

Three suitable EEG products that are available in the current market space were identified. The B-Alert Wireless Headset from Advanced Brain Monitoring Inc., the g.MOBIlab+ from Cortech Solutions, and the Biosemi ActiveTwo from MindWare Technologies Ltd.

Brochures for the three EEG products were acquired and pricing information was obtained through online quotations. Brochures for all three products are available in the Annex A-E.

3.1.2 Product Specifications

Three potential systems were investigated, the B-Alert Wireless Headset, the g.MOBIlab+ and the Biosemi ActiveTwo. While these systems are all capable of monitoring brain activity, they differ in their ability to meet the needs of this project. In the following sections, the basic features of these three systems are discussed and compared.

3.1.2.1 B-Alert Wireless Headset

The B-Alert Wireless Headset has 9 electrodes to monitor EEG signals. Little or no hair or scalp preparation is needed with this system, as each sensor dispenses conductive cream to the scalp for electrical contact. This dispensing system, consisting of four components and conductive cream, must be assembled before each use of the EEG. The wireless system allows the user to move freely, and can be covered by a baseball cap to be worn in public (Advanced Brain Monitoring Incorporated, 2007). For more information and comparisons to the other products, please refer to Table 1 and Annex A.

3.1.2.2 g.MOBIlab+ (8-channel EEG version)

The g.MOBIlab+ has 8 EEG channels and 4 digital channels. It is combined with the g.EEG cap to monitor EEG signals with a range of possible electrodes. The system can operate wirelessly via Bluetooth or through wired USB. Up to 2GB of data can also be stored using a Micro-SD flash memory card (Guger Technologies, 2010). For more information and comparisons to the other products, please refer to Table 1 and Annex B.

3.1.2.3 Biosemi ActiveTwo

The Biosemi ActiveTwo has 32 channels to monitor EEG signals. With this system, scalp preparation time is reduced due to the proximity of the electrodes to the headset's electronic system. The system is connected to the computer through USB for data transfer (BioSemi, 2010; MindWare Technologies LTD., 2010). For more information and comparisons to the other products, please refer to Table 1 and Annex C.

3.1.2.4 Product Comparison Table

Table 1: EEG product comparison

Product B-Alert	**Wireless Headset**	**g.MOBIlab+ (8 channel monopolar EEG version)**	**Biosemi ActiveTwo**
Company	Advanced Brain Monitoring Inc.	Cortech Solutions	MindWare Technologies Ltd.
Company Location	California, USA	North Carolina, USA	Ohio, USA
Channels	9	16 (up to 8 for EEG)	32
Measurements Available	Electroencephalography (EEG)	Electroencephalography (EEG)	Electroencephalography (EEG)
	Electrocardiography (ECG)	Electromyography (EMG)	Electromyography (EMG)
	Electrooculography (EOG)	Electrooculography (EOG)	Electrocardiography (ECG)
		Electrocardiography (ECG)	
		Respiration sensor	
		Photoelectric pulse sensor	
		Galvanic skin response sensor (GSR)	
Sampling Rate	256 samples/sec	256 samples/sec	2048, 4096, 8192, 16384 samples/sec (depending on sample frequency)

Weight	113 g with batteries	360 g with batteries	1100 g (system without headset)
Dimensions (encoder) (mm)	127 x 57.15 x 25.4	155 x 100 x 40	120 x 150 x 190
Power source	2 x AAA 900 mAH NiMH batteries	4 x AA Mignon batteries	25 Watt-hour, 3 cell sealed lead-acid battery
Battery Life	7 hours	25 - 100 hours	5+ hours
Resolution	16 bit	16 bit	24 bit
Dynamic Range	± 1000 µV	± 500 µV	Information not available
Wireless Capability	✓	✓	×
Self-Calibration	×	×	×
Portability	Can operate up to around 10 metres from workstation, laptop, or PDA	Can operate up to around 100 metres from workstation, laptop, or PDA	Wired
Data Storage	Compact Flash Data Storage	Compact Flash Data Storage	
Potential fo r Parallel Experimentation	Multiple headsets can operate within the same vicinity		
Consumables	Electrode Gel	Electrode Gel	Electrode Gel
	Foam Disks	Abrasive Gel	Adhesive Disks
	Sensors can be reused up to 30 times		
Software	B-Alert Acquisition Software	API/ Device Driver	LabVIEW
	Athena Acquisition Software	MATLAB-API	
		High-Speed Online Processing for SIMULINK/ LabVIEW	
		g.Recorder	
		Pocket PC recording software	

Note. Information collected from *EEG Technology Review: W ireless Sensor Headset B-Alert Software Alertness and Memory Profiler (AMP), g.MOBIlab+,* and *Specifications for biopotential measurement system, type ActiveTwo Mk2 with two- wire active electrodes. For cells in the table that are blank, no information could be found for the product's capabilities.*

3.1.3 Suitable Configuration of Products

Since the EEG system selected will be used with multimodal displays, a wireless EEG system would be preferred since this would allow users to move freely. If the experiment requires multiple types of measurements, it might be useful to use one system to collect measurements of other variables (such as respiration, temperature, EKGs), focusing the EEG system on the acquisition of EEG signals.

3.1.4 Ranking

The three products were ranked using the following criteria to determine which EEG technology would be most suitable for the project:

- Portability (wireless capability and weight)
- Cost
- Software (as mentioned in Table 1)
- Interference with other systems
- Integration and software
- Tech support
- Calibration
- Accuracy

In the following sections, the capability of these three systems to meet the above criteria is discussed. The three systems are ranked and the rationale for this ranking has been provided.

3.1.4.1 Criteria Evaluation

In comparison with the above criteria, the following characteristics were noted.

- **Portability** – The Biosemi ActiveTwo is not portable enough for the application in mind. The system is too bulky for the DRDC Toronto project, especially considering the other technologies that will be used, such as a tactor vest and GCS interface. The Biosemi ActiveTwo would interfere with physical movements of the operator, therefore, the Biosemi ActiveTwo was disqualified.

  The B-Alert Wireless Headset is more portable than the g.MOBIlab+, as it is lighter and the entire system is isolated to the headset, so no wiring would impede body movement.

- **Cost** – The costs of the Flexcomp Infiniti and the Biosemi ActiveTwo are well within a price range that will allow the project to stay within budget, as opposed to the g.MOBIlab+ that costs approximately $5000 more per unit. Therefore, the g.MOBIlab+ was disqualified.

- **Interference with other systems** – Because the B-Alert Wireless Headset is connected via Bluetooth, multiple headsets can operate within the same vicinity. The Bluetooth connection should also allow for other wireless systems to operate in the same area as the headset without any interference. There should be no interference with wired systems.

The g.MOBIlab+ is also connected via Bluetooth and should have no interference issues either.

- **Integration and software** – The integration of the B-Alert Wireless Headset is very simple and allows for effective EEG data acquisition. The entire hardware system is integrated into one unit that is part of the headset, and the software is easy and straightforward to use, allowing several different measurements and analysis of the collected data. The g.MOBIlab+ is quite complicated, as the system must be connected to another product by the same manufacturer (g.GAMMAsys) for operation. The device can be integrated into a notebook, PC, or PDA through SIMULINK. This also disqualified the g.MOBIlab+.
- **Technical su pport** – The supplier of the B-Alert Wireless Headset, Advanced Brain Monitoring Inc, provides two days of on-site technical integration and support, the cost of which differs depending on site location. Cortech Solutions, which is the supplier for the g.MOBIlab+ provides a variety of support options to give customers assistance regarding installation, training, and repairs. On-site training requires a nominal fee, while repairs require sending the product back to the company.
- **Calibration** – No self-calibration was explicitly mentioned in the brochures and product descriptions of both the B-Alert Wireless Headset and the g.MOBIlab+.
- **Accuracy** – It is very difficult to objectively judge how accurate these technologies are, as other factors such as proper set-up of equipment play a large part in the accuracy of measurements made by these products.

3.1.4.2 Final Ranking

The products are listed in order of ranking.

1. B-Alert Wireless Headset
2. g.MOBIlab+
3. Biosemi ActiveTwo

3.1.5 Recommendation

Due to time constraints, leasing and evaluation of the three products was not possible. Instead, expertise from other researchers in the field of augmented cognition was relied upon and consultation with the Scientific Authority was required to establish criteria for selecting a product. Through these consultations, criteria for an initial technical assessment were developed and utilized, as described above. It is recommended that the product most suitable for the DRDC Toronto project be purchased and evaluated.

3.2 Preliminary Technical Review of Electrocardiogram (ECG) Technologies

A preliminary technical review of ECG technologies was performed according to the Statement of Work. In this section, the various ECG products and their prices are discussed. Their specifications are compared against project criteria and one of the possible systems is recommended.

3.2.1 Suitable Products

Three suitable ECG products available in the current market space were identified. These consisted of the FlexComp Infiniti from Thought Technology Ltd, the g.USB amp from Cortech Solutions, and the I-330 C2plus 12 channel system from J&J Engineering.

Brochures for the three ECG products were acquired and pricing information was obtained through online quotations. Brochures for all three products are available in the Annex.

3.2.2 Product Specifications

Three potential systems were investigated, the FlexComp Infiniti, the g.USB amp and the I-330 C2plus 12 channel. While these systems are all capable of ECG measurement, they differ in their ability to meet the needs of this project. In the following sections, the basic features of these three systems are discussed and compared.

3.2.2.1 FlexComp Infiniti

The FlexComp Infiniti is the most advanced biofeedback technology available from Thought Technology Ltd. The encoder has 10 channels, each operating at 2048 samples per second. The encoder can be attached to a computer using fibre optic wires and the bundled USB-fibre optics adapter for real time monitoring, or wirelessly with a Bluetooth dongle. A compact flash card can also be used for remote data storage (Thought Technology, 2010a; Thought Technology, 2010b). The software provides a wide range of screen configurations for ECG and other measurements that can be made with the encoder. An example screen configuration is shown in Figure 18, which shows a blood volume pulse (raw) signal, heart rate, and respiration. The shown screen configuration can also display EMG and skin conductance signals. For more information and comparisons to the other products, please refer to Table 2 and Annex D.

3.2.2.2 g.USB amp

The g.USB amp from Cortech Solutions has 16 input channels which can sample with up to 38400 samples per second and four 4 independent grounds. The amplifier is connected to a computer via a USB 2.0 interface for data collection. Various software solutions are available, including support for all features of the amplifier and high-speed online data processing (Guger Technologies, 2009). For more information and comparisons to the other products, please refer to Table 2 and Annex E.

3.2.2.3 I-330 C2plus 12 channel

The I-330 C2plus 12 channel system from J&J Engineering has 12 channels capable of 2-person monitoring at 1024 samples per second. The system is connected to a computer via USB for real time data collection. The software provides feedback screens, audio, and impedance checking (J&J Engineering, 2010). For more information and comparisons to the other products, please refer to Table 2 and Annex F.

3.2.2.4 Product Comparison Table

Table 2: ECG Technologies Comparison

Product FlexComp	**Infiniti**	**g.USBamp**	**I-330 C2plus 12 channel**
Company	Thought Technology Ltd.	Cortech Solutions	J&J Engineering
Company Location	Quebec, Canada	North Carolina, USA	Washington, USA
Channels	10	16	12 (up to 4 for EEG)
Measurements Available	Electroencephalography (EEG)	Electroencephalography (EEG)	Electroencephalography (EEG)
	Electromyography (EMG)	Electromyography (EMG)	Electromyography (EMG)
	Electrocardiography (ECG)	Electrocardiography (ECG)	Electrocardiography (ECG)
	Respiration	Electrooculography (EOG)	Respiration
	Temperature		Temperature
	Skin Resistance/Conductance		Skin Resistance/Conductance
	Blood Volume Pulse (BVP)		Heart Rate Variability (HRV)
	Hemoencephalography (HEG)		
Sampling Rate	2048 samples/sec	38400 samples/sec	1024 samples/sec
Dimensions (enc oder) (mm)	130 x 95x 37	197 x 155 x 40	152.4 x 95.25 x 31.75
Power source	4AA batteries, single-use alkaline	GlobeTek GTM21097-3005 Medical Power supply	4AA batteries, single-use alkaline
Alternate Power Source	4AA batteries, rechargeable NiMH	Rechargeable battery pack	
Battery Life	30 hours typical, 20 hours minimum (alkaline)	10 hours with rechargeable battery pack	Information not available
Resolution	14 bit	24 bit	16 bit

Wireless Capability	✓	×	×
Self-Calibration	✓	✓	×
Compact Flash memory storage	✓	✓	×
Automatic Electrode Impedance Checking	✓	✓	✓
Software and Suites	BioGraph Infiniti	API/ Device Driver	Sensor Test Screen
	Developer Tools	MATLAB-API	Check Signal Screen
	EEG Suite	High-Speed Online Processing for SIMULINK/ LabVIEW	Heart Rate, Respiration, Heart Variability Bands
	Physiology Suite		Breathing Training Screen
			EMG Training Screen

Note: Information collected from *FlexComp Infiniti Hardware Manual, g.USBamp generation 3.0,* and *I-330-C2+ 12 Channel. For cells in the table that are blank, no information could be found for the product's capabilities.*

3.2.3 Suitable Configuration of Products

Since the ECG system selected will be used with multimodal displays, it will be more convenient for the system to be wireless as this will allow users to move more freely. It will also be useful to measure other physiological variables such as blood volume pulse, respiration, and EMG, which the selected EEG does not measure.

3.2.4 Ranking

The three products were ranked using the following criteria to determine which ECG technology would be most suitable for the project:

- Wireless capability
- Sampling rate
- Other available sensors
- Cost
- Company Location
- Software

3.2.4.1 Criteria Evaluation

The ECG technologies considered here were evaluated based on the information provided on Table 2. In comparison with the above criteria, the following characteristics were noted:

- **Wireless capability** – Compared to the g.USBamp and the I-330 C2plus 12 channel, the FlexComp Infiniti is the only system with wireless capability. This was enough to disqualify the the g.USBamp and the I330 C2plus 12 channels.
- **Sampling rate** – Compared to the g.USBamp and the I-330 C2plus 12 channel, the FlexComp Infiniti has the highest sampling rate.
- **Other available sensors** – The Flexcomp Infiniti has the selection of sensors that are most relevant to support multimodal UAV interface design. The gUSBamp does not provide a wide array of sensors.
- **Cost** – The cost of the Flexcomp Infiniti and of the I-330 C2plus 12 channel are well within the price range of the given budget while the g.USBamp is too expensive for this project.
- **Company location** – The company location is optimal for the Flexcomp Infiniti as it is in Canada, making it easier when repairs and replacements are required. The manufacturers of the I-330 C2plus 12 channel and of the g.USBamp are located in the USA.
- **Software** – The I-330 C2plus 12 channel does not have adequate data display in its software package to monitor ECG and other measurements. The Flexcomp Infiniti has the best array of data display screens for supporting multimodal UAV interface design.

3.2.4.2 Final Ranking

The products are listed in order of ranking.

1. FlexComp Infiniti
2. I-330 C2plus 12 channel
3. g.USBamp

3.2.5 Recommendation

Due to time constraints, leasing and evaluation of the three products was not possible. Instead, expertise from other researchers in the field of augmented cognition was relied upon and through consultation with the Scientific Authority, a criteria for selecting an ECG system was established. Through these consultations, criteria for an initial technical assessment were developed and utilized, as described above. It is recommended that the product most suitable for the DRDC Toronto project be purchased and evaluated.

3.3 Technical Evaluation of Psychophysiological Technologies for Multimodal UAV Interface Design

In the previous phase of the project, EEG equipment and ECG equipment were evaluated and selected according to the specified requirements for use as a physiological measurement of the mental and physical load faced by UAV operators. The purchase and delivery process of the relevant technologies was initiated, according to University of Waterloo protocols. The two selected technologies had different purchasing requirements, since one was purchased from within Canada (FlexComp Infiniti from Thought Technology) and the other was purchased from the United States (B-Alert System from Advanced Brain Monitoring).

A cost analysis was conducted with the University of Waterloo purchasing department to guarantee that the equipment was delivered on time and that the project would remain within budget. Extra expenses such as taxes, brokerage fees, shipping and handling were considered in the budget.

After the analysis of costs, suppliers were contacted and the purchases were made. The shipping status of the US product was constantly monitored in order to deal with border issues and assure that the product arrived at the University of Waterloo in time for evaluation and delivery to DRDC Toronto.

Each unit was shipped with a package of accessories that would allow researchers to conduct the required measurements for this project. The components of each purchase are listed in the following sections, organized by manufacturer. Two units of the FlexComp Infiniti and two units of the B-Alert were purchased, along with the accessories and consumables.

3.3.1 Equipment verification

As soon as the equipment arrived, the contents were checked against the purchase orders and everything was accounted for. The purchase tables shown on Table 3 for the items purchased from Advanced Brain Monitoring and Table 4 for the items purchased from Thought Technologies show the contents of each package.

Table 3: Description of items purchased from Advanced Brain Monitoring

Description Quantity	
10 Channel B-Alert Wireless System (with the researcher discount)	2
External Syncing Unit (ESU)	2
Sony VAIO 24-Inch Desktop PC	2

Table 4: Description of items purchased from Thought Technology

Number of Items	**Item Code**	**Item Description**
2	T7555M	FLEXCOMP INFINITI SYSTEM w/
2	SA7700	TT-USB RECEIVER
2	SA7550	FLEXCOMP INFINITI ENCODER
2	SA7900	BIOGRAPH INFINITI SOFTWARE
2	SA7903	BIOGRAPH INFI TUTORIALS CD
2	SA7950	EEG SUITE SW
2	SA7970	PHYSIOLOGY SUITE SW
2	SA7926	REHAB SUITE SW PRO5 PRO FLEX
2	SA7920	BIOGRAPH INFINITI DEV TOOLS SW
2	T9306M	SENSOR, EKG FLEX/PRO KIT
2	SA9306M	SENSOR, EKG FLEX/PRO
2	T8710M	EKG EXTENDER CABLE KIT
2	SA9325	EKG WRIST STRAPS
10	T3425	ELECTRODES 100 UNI-GEL SINGLE
2	T9600	TELE-INFINITI CF

2	SA9600	COMPACT FLASH TELE-INFINITI
2	SA9610	COMPACT FLASH TELE-INFI CD
2	SA9630	CF TELE-INFINITI USB DONGLE
2	T9401M-60	MYOSCAN-PRO 60HZ KIT
2	SA9401M-60	SENSOR, MYOSCAN-PRO 60Hz
2	T8720M	SENSOR EXTENDER CABLE KIT
2	SA9309M	SENSOR, SKIN CONDUCTANCE
2	SA9310M	SENSOR, TEMPERATURE
2	SA9311M	SENSOR, RESPIRATION
2	SA9308M	SENSOR, HR/BVP FLEX/PRO
10	SA2306	HEADBAND EMG
10	T3450	EEG PASTE TEN 20 CONDUCTIVE
10	T3470	NUPREP EEG SKIN PREP GEL 114gm

The shipped equipment was confirmed against the purchase order and catalogued as shown in Figures 1 to 4:

Figure 1: B-Alert System EEG unit from Advanced Brain Monitoring including the data acquisition unit, the sensor strip and the wireless USB adapter.

Figure 2: B-Alert System EEG unit accessories from Advanced Brain Monitoring including the EEG sensors and ECG sensors.

Figure 3: Sony VAIO 24-inches Computers for use with the B-Alert System EEG unit from Advanced Brain Monitoring including the Bluetooth keyboard and mouse.

Figure 4: FlexComp Infiniti unit from Thought Technology including all the sensors that shipped with the unit (except the extra electrodes).

3.4 Preliminary Evaluation of Acquired Psychophysiological Technologies

In order to evaluate the delivered units, operational testing was conducted to assure correct functionality. The units were assembled and tested according to instructions indicated in the manual.

3.4.1 Demonstrable use of EEG Technology in Simulation and its Extensibility for Different Research Settings in the GCS

In the past, EEG technologies have been used for evaluating the pilot's mental workload during flights (Bonner & Wilson, 2002). The use of EEG technology allows for the evaluation of changes in mental workload and brainwaves according to the tasks that the individual is performing. These differences in workload can be used to compare and evaluate different interfaces since they allow for the comparison of baseline data to the workload measured when using new interface designs. EEG technologies could be used to analyse the effects of multimodal interface changes in the GCS interface design.

Another possible use for EEG technologies in support of the GCS interface development could be the integration of psychophysiological data collection devices with the new multimodal interfaces. The integration of the psychophysiological technologies with the GCS interface could help identify instances of high mental workload during UAV operations.

Ultimately, the EEG system provides an objective measurement of the individual mental workload. For the purpose of the GCS UAV multimodal interface design, the EEG technologies provide visualizations of changes in the mental conditions of the operator that are easily detectable and analyzable.

EEG technologies are a powerful tool for evaluating mental changes in task performance due to changes in the interface design, but EEG units must be selected according to the specific requirements for each project. The ability to conduct more advanced analyses is directly related to the number of channels and the software in use since more advanced systems available on the market provide more channels than the acquired systems (32 channels for more advanced systems vs. 9 channels on the acquired units). However, it is also necessary to consider the time commitment required to set up the unit under experimental conditions, since additional channels require more set up time.

The B-Alert system has 9 sensors in a wireless headset. The software that was provided with the unit also allows a detailed analysis of the data. However, the set-up and clean-up of the system is time consuming, making its use for a large number of participants in a short time span difficult. Setting up the technology takes approximately 20 minutes while cleaning the sensors takes approximately 30 minutes, but more time is needed to air dry the cap after washing.

Even with all these limitations, some of possible uses in the GCS interface design project include:

1. Evaluation of new interfaces
2. Evaluation of multimodal interfaces
3. Evaluation of mental workload during different stages of the flight, both in simulated conditions and real flights
4. Evaluation of different UAV aircraft and control technologies, considering the different workload required to control the aircraft
5. Evaluation of different training programs

3.4.2 Demonstrable use of ECG Technology in Simulation and its Extensibility for Different Research Settings in the GCS

ECG technologies have been extensively used to evaluate pilot performance. For example, they have been used to evaluate the perceived risk by pilots (Sharma, 2006) and mental workload during flights (Wilson, 2009). Bonner and Wilson (2002) applied these technologies for testing and evaluating different aircraft systems and De Rivecourt, Kuperus, Post & Mulder (2008) applied them in the analysis of changes in mental effort during simulated flights.

From the literature above a few possible uses for ECG systems in the context of the GCS can be devised:

1. Comparison of perceived risks between manned aircrafts pilots and UAVs operators for the same mission type
2. Evaluation of the consequences of the difference in the perceived risk in the operators performance
3. Evaluation of mental and physical workload for the UAV operator
4. Evaluation of new interfaces, cockpits and UAVs
5. Evaluation of training and testing simulations

Other possibilities include the use of ECG to measure arousal, perception of changes and physical workload. Sharma (2006) uses ECG monitoring to assess pilot’s heart interbeat intervals and relates this measure to evaluate perceived risk of the consequences from their inability to perform a task adequately. This measure could be used to improve the GCS control systems and apply concepts of adaptive automation to the GCS. Wilson (2009) presents ECG as another tool for test and evaluation of new aircraft systems. ECG is shown as a non-intrusive measure that can provide additional information to the evaluation team other than the typical performance and subjective measures usually collected. For the purposes of GCS interface development, ECG could be used to evaluate different control interfaces or different situations in pilot control.

The connection between mental workload (as stated in the previous section) and ECG signals is explained in detail by Nickel & Nachreiner (2003). Therefore, all the measurements stated above as a measurement of mental workload can be complemented by ECG and other physiological measurements provided by the FlexComp Infiniti unit with the objective of measuring operator mental and physical workload. Simple ECG measurements can be done using both the FlexComp Infiniti (with the appropriate sensors) and the B-Alert System.

3.4.3 Integration Feasibility of EEG Technology with another Psychophysiological Technology for the GCS Interface

The simultaneous use of an EEG system and an eye tracker system would allow the integration of the analysis of gaze and eye motion (indicating where the participant is looking and how the gaze changes over time) with the corresponding brainwaves. Eye fixations can be used to determine commonly viewed display elements and also to identify potential layout problems if commonly viewed elements (in the case they are logically relevant) are spaced far apart on the display. It is well known that one issue with only collecting eye-tracking data is that fixations can indicate both areas of high interest, as well as areas of confusion. Combining eye-tracking data with EEG data may reveal which areas of the interface are associated with higher levels of mental workload. By combining this information from the eye tracker with EEG information, it is possible to identify design features that reduce operator mental workload and therefore develop better designs . In particular, when multimodal interfaces are being used, operators may show different visual attention patterns in a multimodal interface compared to a solely visual interface. Designing interfaces that require less eye movement, and potentially, less effort from the operator could ultimately result in better operator performance.

A main characteristic considered in the evaluation of the EEG technology was the portability of the unit. Compact and portable units facilitate the integration of multiple psychophysiological technologies, providing more information about the psychophysiological state of the pilots with less movement restriction than heavy or bulky units. The fact that the units are portable facilitates the integration with technologies such as eye trackers that require a larger setting for the acquisition of data. Also, portable units reduce the physical wired connections between the participant and the acquisition computers, reducing physical impediments to operator performance.

Since the B-Alert unit is placed on the top of the head (Figure 5) and there is no interruption of the line of sight, integration with an eye tracking system is possible and no physical interference would be expected from the interaction of these two technologies. We did not have the opportunity to evaluate the presence of electro-magnetic interference from the two units, but considering the new technological developments and the use of standardized communication protocols and technologies such as Bluetooth; electro-magnetic interference would be unlikely.

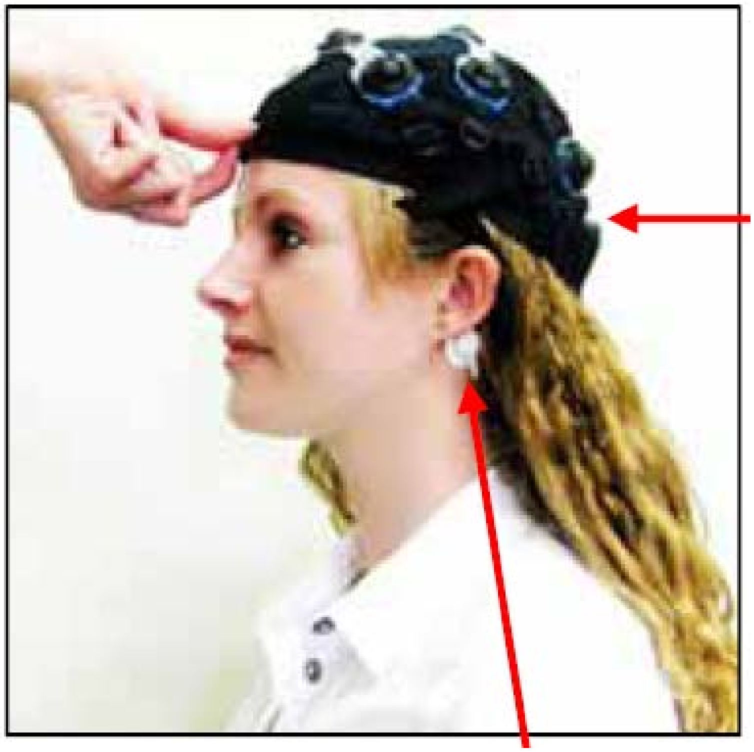

Figure 5: B-Alert System EEG headset assembly example from Advanced Brain Monitoring.

Depending on the type of eye tracking system to be used, some integration issues may need to be addressed since some eye trackers are also head-mounted. Thus, for integration with the B-Alert system, it is recommended that an eye tracker system be selected that does not need to be head-mounted.

Factors to consider when integrating EEG and eye tracking systems include:

1. The bulkiness and portability of the system– it is important to consider how these systems would affect participant mobility and how the reduced mobility would affect the results of the research. Regarding portability, researchers should consider what tasks participants will be required to perform (regarding motion and freedom of movement) in order to assess the portability requirements for the measurement system.
2. The effect of system on the performance of the individual – researchers should consider how that measurement system will affect the performance of an individual. The presence of leads and wires can impede a participant's performance, imposing physical restriction, as well as detracting from the realism of a simulated operational environment.
3. The potential for interactions between wireless systems – older wireless systems can cause unwanted interactions with other wireless systems. Therefore, it is important to select systems that use well established communication protocols that avoid these interactions.
4. The potential for electromagnetic interference – electromagnetic interference can occur when using wireless systems in environments with abundant electro-magnetic radiation. Such environments can affect measures collected by the system or "rupture" pairing between units.

When using the selected EEG technology in combination with an eye tracker system that does not require parts of the eye tracker to be physically connected to the participant, the first two factors do not need to be considered since the system does not add any component that limits or changes the performance of the individual. One remaining concern would be external interference and internal interference between the eye tracker and the EEG system if both systems use non-standardized wireless technology. In order to evaluate such interference, it would be necessary to have the units available for performance testing prior to purchasing or to rely on the wireless communications protocols developed by the manufacturers.

The B-Alert system allows real-time exporting capabilities via TCP/IP or UDP/IP that can provide a useful integration opportunity. One could use the SDK provided with the B-Alert system or stream data through a dynamic link library. This data could then be collected on a second computer using TCP/IP protocols.

It should be noted that selection and evaluation of the eye-tracking system was not within the scope of this project.

3.4.4 Integration Feasibility of ECG Technology with other Psychophysiological Technology for the GCS Interface

In the previous section, the integration of the B-Alert system with an eye tracker system was discussed. In order to broaden the possibilities and discuss a wider variety of integration alternatives, in this section, the integration of several physiological measurements provided by the FlexComp Infiniti will be discussed. De Rivecourt et al. (2008) present an article where an ECG system is integrated with an eye tracker system to measure momentary changes in mental effort during simulated flights, while Wilson (1992) discusses the practical considerations and precautions of using cardiac and respiration measures. These authors provide some examples of integration possibilities that can be used as a starting point for the integration of these psychophysiological technologies in the GCS multimodal interface scenario.

1. ECG and respiration frequency – The FlexComp Infiniti has the capability to provide numerous measures, allowing parallel measurements of ECG, EEG, EMG, hemoencephalography respiration frequency, blood volume pulse, temperature, and skin conductance; being only limited by the number of channels available. These variables provide several interesting integration possibilities such as: ECG and respiration frequency – Since heart rate and respiration rate correlate with arousal and mental workload (Wilson, 2009), analysis of these physiological measures may improve the accuracy of arousal and mental workload monitoring. Such measurements could be used as input into a UAV command centre environmental control system that would adjust the operator environment to improve performance. An example would be a control system that would adjust the air mixture of the command centre according to the level of workload applied to the operator. Measurements of respiration frequency could be used as an input to an air-mixture system that would increase the concentration of oxygen in the breathing mixture in more physically and mentally demanding situations. This would reduce the respiration frequency and therefore, the physical workload. Note, this would require having a controllable physical environment for the UAV operator.

2. ECG and temperature variation – Here it may be possible to control the pilot's environment to improve performance using some of the variables measured by the

FlexComp Infiniti. Several different regions of the operator’s body can have temperature changes during high workload moments. Temperature and ECG changes may be combined to determine triggers for adaptive displays. Although futuristic, a system could be devised to control seat or air temperature in high workload situations, reducing the operator’s discomfort and possibly improving performance.

3. ECG and EMG – EMG provides an effective tool to measure muscle usage, and consequently, muscle fatigue after a long period of muscular effort. Muscle fatigue can result from a repetitive movement with high muscular effort is performed. This could be used to trigger adaptive display changes to reduce repetitive actions. Integrating EMG and ECG would allow for correlation between increased workload and change in muscular activities, allowing the use of adaptive-automation in critical moments.

The combinations of the physiological measurements collected by the FlexComp Infiniti create a large number of integration possibilities with the use of a single piece of equipment. If all the possible measurements provided by the FlexComp Infiniti are considered, it is easy to collect a wide range of data (ECG, EEG, EMG, temperature, skin conductance, blood volume, heart rate, respiration frequency and volume etc.). The variables collected will depend on the requirements of each experiment, allowing a great diversity of experiments to be run using the same FlexComp Infiniti unit.

The data integration between the acquisition software and the analysis software needs to be conducted after the data has already been acquired since the FlexComp Infiniti does not possess a real-time export feature. The solution for the researcher would be to acquire the data and export it later to an external comma separated values (CSV) file that could later be imported into analysis software. This file would contain the data acquired and a timestamp that could be used for integrating it with data from other devices.

3.4.5 Integration Feasibility of EEG technology with other two psychophysiological technologies for the GCS interface

Wilson (2009) published a paper on the integration of multiple psychophysiological measurements for pilots during flight. These measurements include: heart rate, heart rate variability, eye blinks, electrodermal activity, topographically recorded electrical brain activity and subjective estimates of mental workload. Many of these measures could be executed by the B-Alert system and the FlexComp Infiniti system in conjunction with the use of an eye tracker. The integration discussion here considers any eye tracker system available on the market and is proposed only as an integration possibility.

One concern with integrating several different measuring devices is the possibility of interference. The FlexComp Infiniti and the B-Alert systems use Bluetooth connectivity and therefore have no undesirable wireless communication interference with each other. Furthermore, in the case of an eye tracker that is not mounted on the subject, no effect would be seen in the measurements since no direct connection paths exist between the eye tracker and the EEG or ECG equipment. In this case, no current would flow from the eye tracker to the ECG or EEG system, creating noise in the measurements.

The B-Alert system and the FlexComp Infiniti system have great potential to be effective evaluation tools for the psychophysiological changes generated by the GCS’s UAV multimodal interface design. The integration of different physiological variables measured by these equipment would allow for analysis of the physiological changes, providing insight into how to improve the performance of the operator.

One overall issue to be considered is the physical bulkiness of the psychophysiological technology to be used. With multiple sensors and leads, the experiment participant will need to be careful in order to avoid disconnecting the sensors. This could unnaturally restrict their movement and potentially result in some additional fatigue during long experiment sessions. This should be considered in the design of experiments that will use this equipment.

3.4.6 Integration Strategy Recommendations

The integration of the B-Alert system and the FlexComp Infiniti can be discussed from the perspectives of physical integration and data integration. The first part of the discussion will present advantages and issues in the integration of these technologies, while the second, how to integrate the collected data.

Physical Integration

The portability and the wireless synchronization interfaces allow these units to be used simultaneously. These units were developed to allow participants to move freely and perform other tasks while their physiological variables are measured.

Participants will perform a task with several leads and sensors connected to their body. Their performance can be affected both by physically constricting their movement with the leads and sensors, and psychologically creating an environment that does not resemble the real world scenario in which they usually perform. Physical and electromagnetic interactions can also occur if the psychophysiological units do not use standardized communication protocols that avoid cross-talking or when adequate assembly is not performed.

In this section we discuss the overall bulk of the system, and the setup time when running participants. It is important to define the purpose and the importance of each variable measured since adding extra sensors might affect participant performance. It is important to balance the need of having a variable for analysis versus the physical and mental demand that measurement could exert on the participant.

System Bulk: Each intended variable to be measured will require a set of sensors that must be connected to the participant. By adding several different pieces of equipment, the bulkiness of the system can further limit the movement of the participant and interfere with the results by making the task more difficult for the participant.

Thus, it is important to focus on wireless technologies that can communicate measurements without the need for cumbersome wires, so that the participant is as comfortable as possible. For the acquired equipment in this project, wireless capability was a preferred characteristic. Wireless technology allows for integration with other measuring devices with minimal physical impedance. As said before, with the acquired equipment the following physiological activities can be measured:

- EEG
- ECG
- Blood volume pulse
- Temperature

- EMG
- Respiration
- Skin conductance

All these measurements are possible using just the FlexComp Infiniti, thereby reducing system bulk by using a singular unit to obtain multiple measures. However, EEG measurements with the FlexComp Infiniti could be quite cumbersome with many leads and sensors (as shown in Figure 6). In contrast, the B-Alert system focuses on more detailed measurements of brain waves (EEG) and has a simpler measurement system for the measurement of EEG signals.

Figure 6: Example of an experimental setting using the FlexComp Infiniti, from the Thought Technology website.

In an integration of a larger number of measurements with the use of a third system such as an eye tracker system, the same considerations about bulkiness apply, particularly if the eye tracker is head-mounted.

Set up time per participant: An important consideration for experiments using this equipment will be the number of participants versus the number of sensors to be attached to each individual. Set up and clean up of the system for the next participant can take up to a couple of hours. The researchers need to consider this limitation before scheduling the experiments. A couple of dry-runs should be done to make sure that the time necessary to set-up the units and clean them up is considered in the scheduling process. Another possibility is the acquisition of extra PET strips, caps and sensors that would allow the use of the device in a larger number of participants in the same period of time.

Data Integration

The collected data can be exported to external software and integrated into a single analysis. The exported data should include time stamps that can be used as a synchronization trigger that would allow the information from the B-Alert and the FlexComp Infiniti to be synched into a single data package.

Another characteristic that can be used as a synchronization trigger is the ECG signal. Since both the B-Alert and the FlexComp Infiniti systems can acquire ECG data, a specific peak could be used to synchronize the data.

These analyses and integrations would require a different platform since the bundled software does not allow this type of data integration. Software such as Matlab could be used for this purpose. The B-Alert system includes a TCP/IP or UDP/IP real-time acquisition streaming capability that would allow the data to be exported in real-time to a 3rd party analysis software. The Flexcomp Infiniti does not possess this ability. Therefore, to integrate the data, first the researcher would need to acquire the data using the proprietary software, export the data to a file and later analyse it with 3rd party software. This would require an extra step to the researcher but it is still feasible.

Integration possibilities for the data acquired by the B-Alert system and the FlexComp Infiniti were already presented in the previous sections.

3.4.7 Documentation of All Evaluations Performed

When it arrived, the equipment went through a simple initial verification to make sure all the items were shipped. For a functional evaluation, a simple experimental setting was simulated to see how the equipment would perform. The units were assembled and connected to a participant. For each sensor, the particular variable being measured was varied to check the system response. All of the included sensors were tested.

The simulated setting consisted of an environment that allowed the participant to widely vary all the variables being measured. In this case, we used a simple setup in an empty room where the participant could move freely (testing the wireless connectivity) and also change the variables being measured. Through some slight physical activity, it was possible to notice changes in the ECG, EMG, peripheral temperature, blood volume pulse and respiration. A simple comparative test of arousal in a rest state and moments after the physical activity allowed testing of the skin conductance sensors.

Maintaining connectivity is an issue in wireless systems and data loss in an experiment would be a great concern. As a result, simple synchronization and connectivity tests were conducted to determine that the equipment maintained a robust connection with the data collection computer. Also, the two systems were examined in terms of hardware and software setup procedures in order to check if it matched the manufacturer instructions.

3.4.7.1 Initial Evaluation

As previously stated, a visual evaluation of all the components was performed as soon as the units arrived. Every accessory was checked against the purchase order and the units were stored until further testing.

From this initial evaluation, all the units delivered were consistent with the purchase order. The only issue detected was that all the documentation and software from the B-Alert system came pre-installed on the computers and without hardcopy. A copy of the manuals was made into a DVD and the software was requested to the manufacturer and also copied onto a DVD for delivery to DRDC Toronto.

Due to time constraints, it wasn't possible to evaluate the units before purchase. Therefore, the experience of other researchers in the field of augmented cognition that had previous experience with these units was relied upon.

3.4.7.2 Functional Evaluation

The functionality of the received units was subsequently evaluated. Each unit was assembled according to manufacturer instructions and connected to the individuals. The test setting was assembled and the units were evaluated according to their overall performance, synchronization performance and software performance. Each unit was tested on two different individuals, allowing the evaluation of each unit on two different users with distinct head sizes and body builds. One of the individuals was a large male and the second individual was a small female. The distinction in participant size resulted in different levels of difficulty in setting up the units. All the received units were individually tested to assure that they are functioning properly.

Some measurements using the sensors were performed to evaluate each unit and each matched the manufacturer specifications and the project requirements.

3.4.7.2.1 Synchronization Performance

Since the units have wireless capability, it was necessary to test and evaluate the wireless transmission system. This analysis was based on two main factors: initial synchronization and data transmission. The evaluations will be separated by unit type.

B-Alert System by Advanced Brain Monitoring

This unit uses a special external syncing unit as shown in Figure 7. This unit connects to the computer via a USB interface, which allows for connection to the headset. Since the computer used with these units already came prepared for data acquisition, it was not possible to evaluate the initial pairing process.

Figure 7: External syncing unit for the B-Alert System from Advanced Brain Monitoring.

To use the headset, it is necessary to plug the external syncing unit into an USB port. A flashing red light appears, stabilizes to on and then turns off. As the red light turns off, a separate green light flashes and stabilizes indicating that the connection is complete. The green light stays on when the headset is turned on, indicating the headset unit is connected to the syncing unit (as described on the manual). The unit remains synced and streams data while within Bluetooth range and with sufficient battery. This unit has an internal battery that requires recharging after each use.

FlexComp Infiniti by Thought Technology

This unit was shipped with a Bluetooth dongle used to pair this unit wirelessly with the computer. After setting up the drivers and installing the synchronization software, the unit paired easily with the computer. This unit uses a Compact Flash Bluetooth adapter that makes transmission of data from the unit to the computer a simple task.

The USB dongle and the Compact Flash Bluetooth card are shown in Figure 8 and Figure 9 below.

Figure 8: Bluetooth dongle required for the synchronization of the FlexComp Infiniti from Thought Technology.

Figure 9: Compact Flash Bluetooth adapter for the FlexComp Infiniti from Thought Technology.

The initial synchronization only required identification of the unit to be synced with the computer. All instructions are described in detail in the manual.

After identifying the FlexComp Infiniti unit on the computer, all that was necessary was to turn on the unit while the Compact Flash Bluetooth card was inside the computer and start the acquisition software. The participant moved freely without losing connection (while within the range of the Bluetooth).

For the purpose of the test, the unit was connected to the individuals for a period of up to 6 hours without showing any transmission issues.

Overall, the wireless transmission systems indicated that the units worked according to manufacturer specifications.

3.4.7.2.2 Unit Performance

The evaluation of the units will be separated into unit set-up, unit operation and unit clean-up. For each section, images of the procedures will be presented.

B-Alert System by Advanced Brain Monitoring

Unit Set-up – This was a difficult process that required filling each sensor with conductive electrode cream with a tight seal in order to get a good connection (the sensor components are shown in Figure 10). The sensors are made of plastic and consequently, due to their design, are slightly fragile and prone to breaking. After assembling the sensors, they are connected to the PET strip which connects the sensors to the B-Alert system and the cap. After connecting the PET strip to the cap, setting up the headset on the participant can be a little tricky with larger heads but with enough experience, this should not be a problem. Adding the acquisition unit (shown in Figure 11) to the cap and connecting the PET strip is an easy task. The main difficulty during set-up is assembling the sensors. In total, set-up of the entire system required about 20 minutes. Figure 11 shows the unit already assembled. In order to simplify the process and to avoid spending consumables, only 3 sensors were used.

Figure 10: Sensors and connective electrode cream for the B-Alert System from Advanced Brain Monitoring

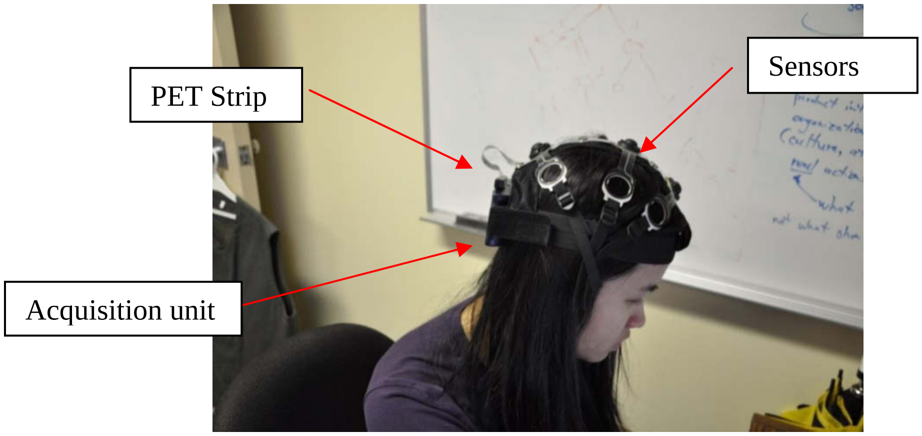

Figure 11: B-Alert System by Advanced Brain Monitoring assembled (using only 3 electrodes).

Unit operation – After unit set-up, the acquisition software must be activated. While the unit is within Bluetooth range, the participant can freely move (as shown in Figure 12) without losing connection to the computer. Some artefacts will be seen when the participant moves, but the connection will remain active. There is no need to interact with the unit during the operation phase unless the sensors lose connection. In this case, more conductive gel should be added underneath the sensors.

Figure 12: B-Alert System from Advanced Brain Monitoring unit assembled and allowing the participant to move freely.

Unit Clean-up – Cleaning this unit for subsequent use is quite complicated. The process consists of disassembling each sensor, washing them individually with soap and water, cleaning the PET strip and washing the cap. Since the sensors have a tendency to break easily, disassembly must be performed with care. Washing the sensors individually can be time consuming, but there are instructions in the manual outlining group cleaning of sensors.

The PET strip can be cleaned with rubbing alcohol. The cap needs to be washed thoroughly after each use since gel tends to leak onto the cap. With only one set of sensors and a single cap, it would be difficult for data to be collected from more than two participants per day.

FlexComp Infiniti by Thought Technology

Unit Set-up – The set-up of this unit was easy and intuitive. Leads are used to connect the unit with corresponding sensors and electrodes that were placed on the participant. Next, the Bluetooth Compact Flash card needs to be inserted in the Flexcomp Infiniti acquisition unit and synched with the computer (better described in the previous section). Each sensor is connected to the unit and the leads are connected to the sensors and electrodes. Each sensor type has different instructions for their individual set-up (better described in the manual on pages 18 to 27).

Both disposable and reusable electrodes are available for a majority of the sensors. Non-disposable electrodes require some clean-up after each use.

In order to reduce interference of participant movement caused by the presence of leads, it is important to attach the leads to the participant’s body using straps.

The sensors require some skin preparation before use. Any skin that will be in contact with the electrodes must be cleaned with the supplied skin prepping gel and conductive gel must be applied between the sensors and the skin (for electrodes that do not include gel). The sensors that do not use electrodes do not require skin preparation before use. Figure 13 shows ECG sensors attached to the participant’s wrists and the blood volume pulse sensor ready for set-up.

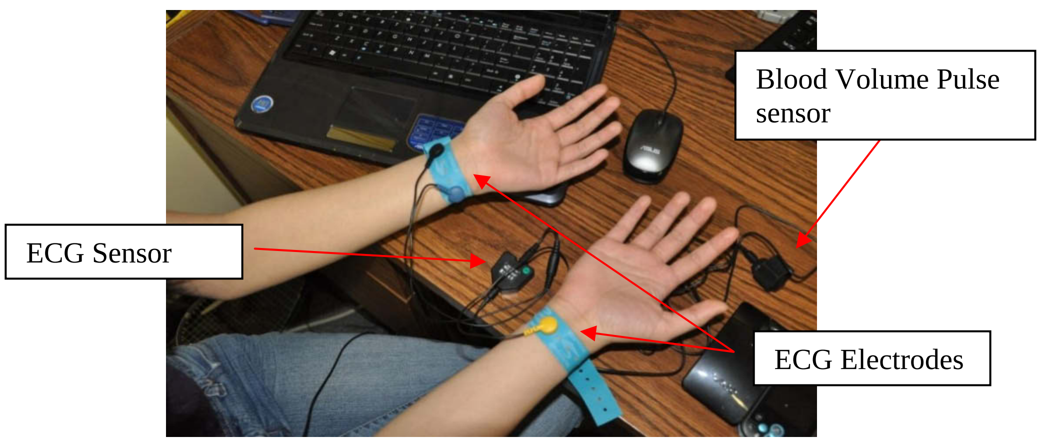

Figure 13: FlexComp Infiniti by Thought Technology system assembled with ECG wrist straps and blood volume pulse sensor.

Unit operation – After setting up the unit, no additional input is necessary. All channels transmit data via Bluetooth to the computer for processing, allowing the participant to move freely without losing connection with the computer. The unit can be seen in use in Figure 12.

Unit Clean-up – The disposable sensors can be discarded and the reusable sensors can be cleaned with rubbing alcohol. The cleaning process is quick and simple since most of the electrodes can either be disposed after use (self-adhesive disposable ones) or easily cleaned (reusable ones). The leads and the unit itself can be cleaned with rubbing alcohol.

3.4.7.2.3 Software Performance

The software was evaluated according to the following criteria:

1. Stability – how the system performs and how the computer responds to the software
2. Possible analysis – variety of analyses that the software can develop with the data
3. Displays – variety of ways that the information can be displayed
4. Flexibility – how the system can be adjusted to the user needs
5. Exportability – easiness to export the data to other software

The evaluation will be presented as a table in Table 5.

Table 5: Characteristics of the software included in each package.

Evaluation Criteria /Product	**B-Alert System from Advanced Brain Monitoring**	**FlexComp Infiniti from Thought Technology**
Stability	This system uses demanding software that requires a lot of memory and processing time. At times, the computer became unresponsive and the software would either crash or freeze. This software was developed to run on a 32-bit operating system. Since it is running on a 64-bit system, the delay and instability of the software may be the result of running on a system that it was not designed for. The system uses two programs in parallel: one for capturing the raw data and one to present the analysis. This further decreases computer performance speed. (Figure 14 and Figure 15)	The software suite used by this unit is very stable and performs without affecting the computer's overall performance. All the information is presented in a single piece of software as shown on Figure 18. Figure 19 and 20 show some of the possible displays. Figure 21 shows some of the choices of displays.
Possible analysis	This system has a limited number of analysis and data processing options: workload and distraction measurements, alpha, beta, theta and sigma waves mapping and channel data wave display. This system lacks a Software Suite as was provided with the FlexComp Infiniti. This software focuses more on the collection of raw data. A few analyses such as mental workload and Alpha, Beta, Sigma and Theta waves are also readily available.	This unit comes with a strong analysis suite. It allows for data processing ranging from simple raw data collection to complex analysis of processed data. The suite has two different types of software: the Rehab Suite and the Physiology Suite. Each of these suites analyses and processes the information in a distinct manner. The Physiology Suite focuses on displaying physiological data, while the Rehab Suite processes and integrates the data into information useful for rehabilitation purposes. This system provides a large array of possible analyses and data processing options.
Displays	This system is limited to displaying the raw data collected	This software suite provides a number of different information

	on each sensor and a standardized display with complex views of workload, heart rate, alpha, beta, sigma and theta waves.	displays: 1. Individual sensor raw data 2. Multiple sensors raw data 3. Individual sensors processed data 4. Multiple sensors processed information 5. A combination of the above
Flexibility	This software allows for data visualization using pre-established configurations. This software package lacks a “developer tool” to allow users to adjust the data acquisition screens to the researcher individual needs. Reports for the data collected can be generated, but they are limited to preset formats already defined by the manufacturer. If the user wants to export the data into customized reports, it must be exported to other software for processing.	This software includes developer tools with channel editors, screen editors and script editors. This software is very flexible and allows for a larger number of adaptations and adjustment to meet researcher’s needs such as different acquisition modes, different displays, integration of data, etc. Such developer tools will be important for the integration of the collected data with other applications. This software provides a very advanced analysis and visualization tool, being flexible, strong and stable at the same time.
Exportability	Data can be streamed through a UDP/IP interface for integration with other software.	Data can be easily exported to an external text file. The export setting allows a detailed selection of the data you want to export. This system doesn’t have a real-time data exporting feature. In order to export the data, the researcher would need to acquire it first with the included software and later export it to a file and integrate it with data from other equipment through a 3rd party software.

Figures 14 and 15 present the interface for one of the tests conducted with the B-Alert System software. In order to simplify the process and to avoid spending consumables, only 3 sensors were used. Figures 16 and 17 present the same interfaces using pre-loaded data from the manufacturer. In this interface, all sensors are active.

Figure 18 shows a screen with multiple variables displayed during testing of the FlexComp Infiniti software. Figures 19 and 20 show the screens for blood volume pulse and ECG measurements correspondingly and Figure 21 shows some of the several possible data displays available to researchers.

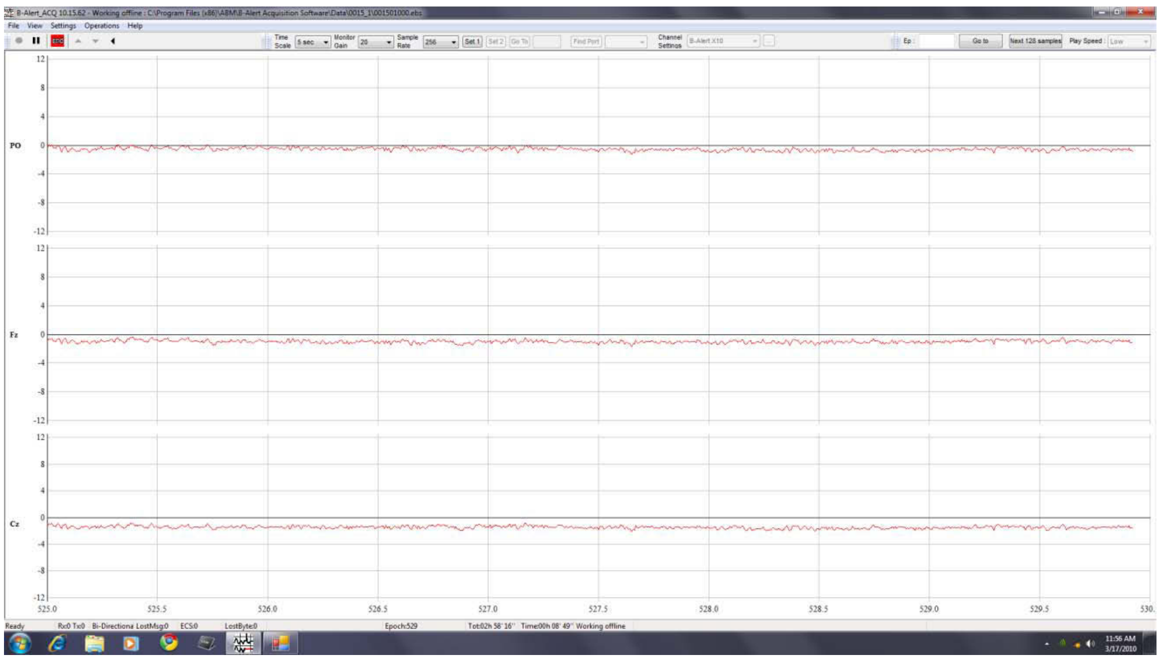

Figure 14: Advanced Brain Monitoring (B-Alert System) acquisition software showing the signals collected by the 3 sensors that were active at the moment (sensors PO, Fz and Cz).

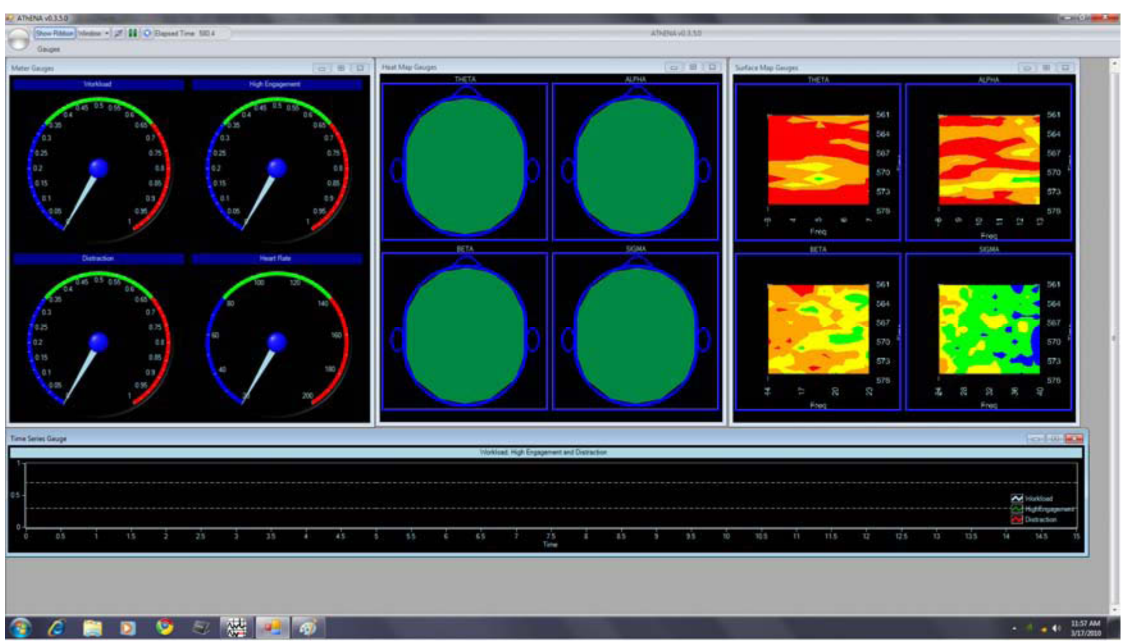

Figure 15: Advanced Brain Monitoring (B-Alert System) visualization and analysis software where it is possible to visualize from the top left corner, clockwise, Meter Gauge displays (showing the level of workload, high engagement, distraction and heart rate), Heat Map Gauges

displays (showing the theta, alpha, beta and sigma heat maps), the Surface Map Gauges displays (showing the theta, alpha, beta and sigma surface maps) and the bottom the Time Series Gauge display (correlating in a time series the display of workload, high engagement and distraction).

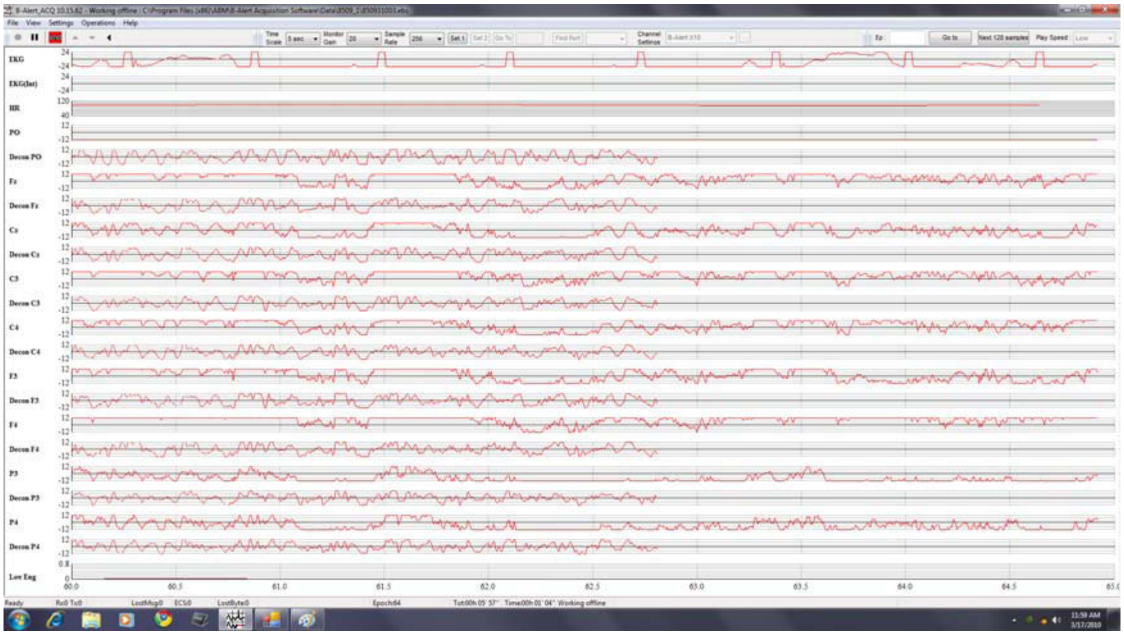

Figure 16: Advanced Brain Monitoring (B-Alert System) acquisition software using the pre-loaded data that the manufacturer sent with the unit. In this display it is possible to visualize all the channels collected by the unit and its variations.

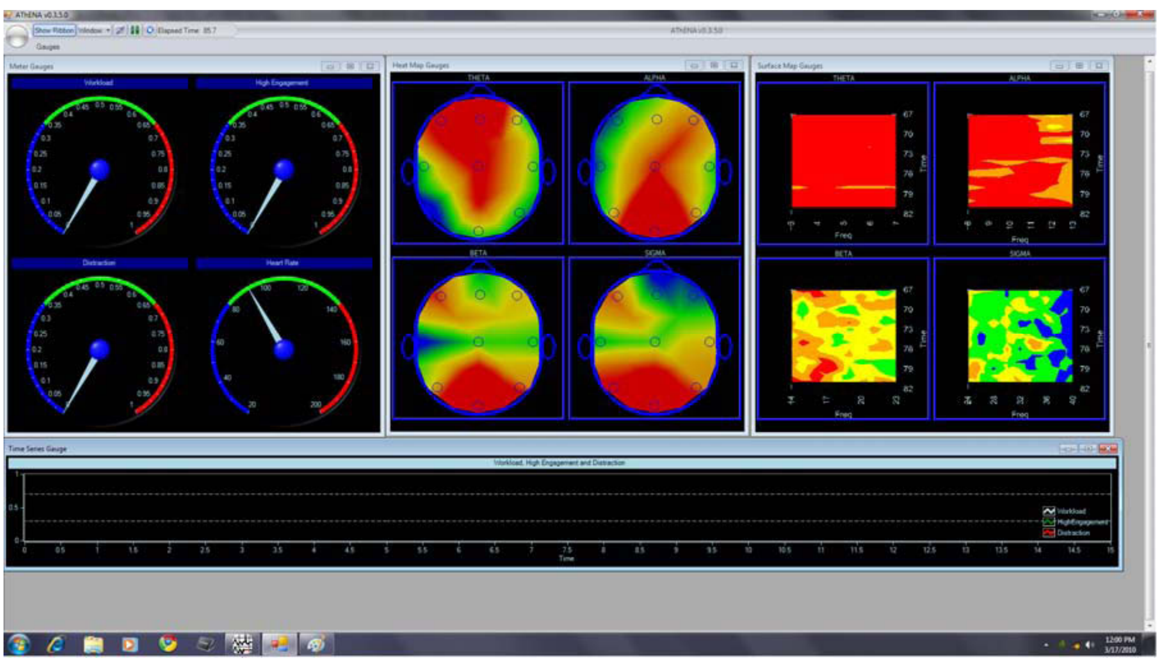

Figure 17: Advanced Brain Monitoring (B-Alert System) visualization and analysis software using the pre-loaded data (same displays shown on Figure 15 but using the pre-loaded data in order to show the functionality of all displays).

Figure 18: Multiple signal information provided by the Infiniti Software System by Thought Technology (using the FlexComp Infiniti unit).This display shows the EMG levels, the Skin Conductance, the Blood Volume Pulse and the Respiration levels.

Figure 19: Display with the Blood Volume Pulse and the instructions on how to set up the sensors in the Physiology Suite by Thought Technology to be used with the FlexComp Infiniti.

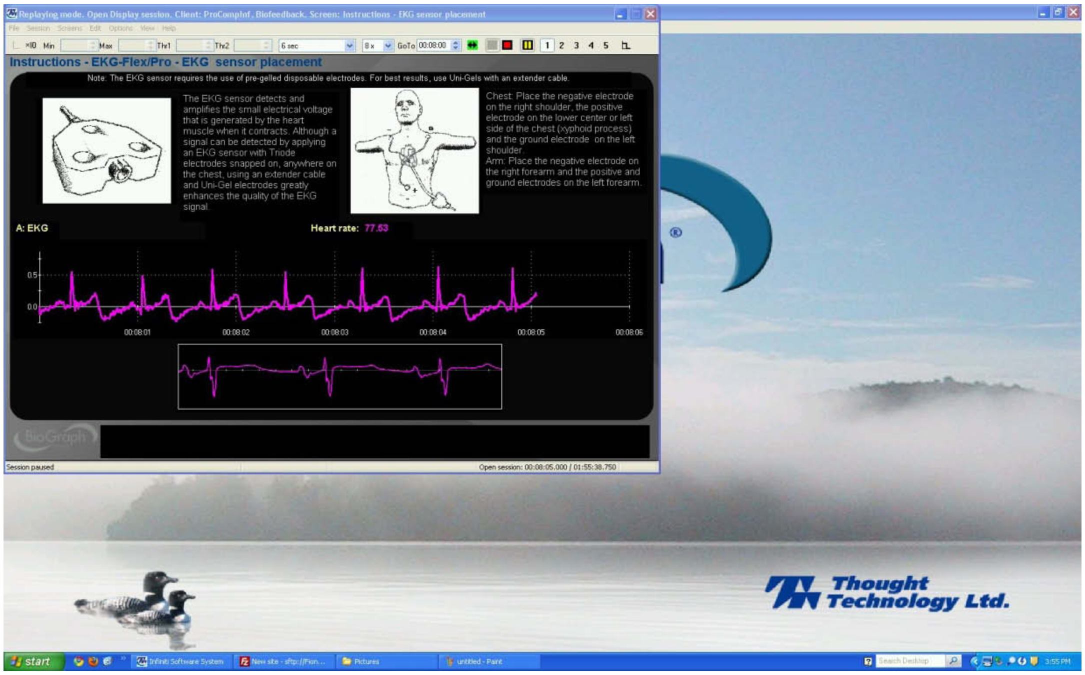

Figure 20: Display with the ECG and the instructions on how to set up the sensors in the Physiology Suite by Thought Technology to be used with the FlexComp Infiniti.

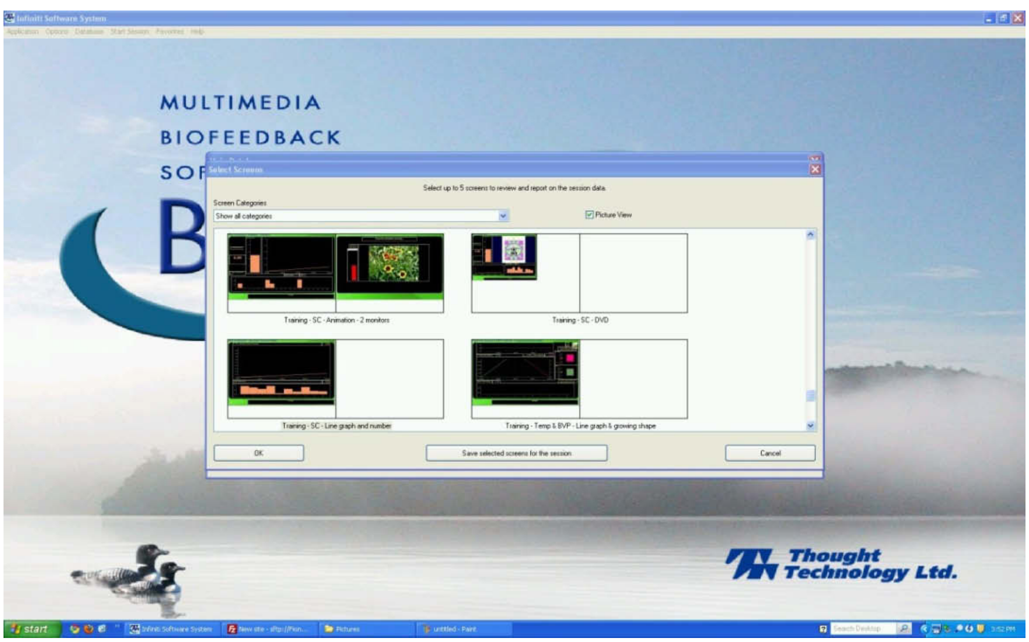

Figure 21: Choices of displays in the Physiology suite or Rehab Suite by Thought Technology to be used with the FlexComp Infiniti unit.

3.4.7.2.4 Final Evaluation Results

All four acquired units (two B-Alert units and two FlexComp Infiniti units) are functioning according to manufacturers' specifications. These systems can be easily adapted to the requirements of the DRDC GCS multimodal interface design research project, as well as other research.

3.4.7.3 Detected Issues

In this section, the disadvantages and difficulties of the acquired systems are discussed. The advantages and support for purchasing these units has been discussed in previous sections.

B-Alert System – the difficulties and problems detected and faced were:

- Sensors are difficult to set-up.
- Sensors are difficult to clean, requiring total disassembly of each sensor and cleaning of each individual piece.
- Sensors are fragile and prone to breaking.
- Cap requires washing after each use.
- Sensor strip came only in small and medium sizes.
- It is not a good experience for the experiment participant since the gel gets all over the participant's hair, therefore the use of this unit should be limited to cases where a detailed analysis of the brainwaves in necessary. This is a characteristic of most EEG systems.
- Internal battery does not allow spare batteries to be used, requiring a recharge between uses to assure that the unit has enough charge for the whole experiment.

According to the manufacturer, the medium sized cap could almost be used as a one size fits all cap, with the exception of very small head sizes. Therefore, for more experienced researchers, this lack of different cap sizes might not be an issue as they should, with practice, be able to adjust the headset appropriately to fit larger heads.

The most significant issue is the time required to assemble and disassemble the B-Alert units.

During use of the B-Alert unit, the following aspects must be taken into consideration:

- Due to the difficulties in assembling and disassembling the units, they should be used for longer and more detailed experiments.

- The system is structurally solid and allows a wide variety of measurements and analyses. However, due to the discomfort imposed on the participant, its use should be restricted to experiments that require a detailed analysis of the participants' brain waves. If only a simple analysis is necessary, the FlexComp Infiniti has a sensor (not acquired in this purchase) that allows simple EEG measurements.

FlexComp Infiniti – the difficulties and problems detected and faced were:

- Leads seem to be fragile
- Some sensors are really difficult to attach (e.g. EMG sensors and the EMG electrodes)
- Some sensors are too bulky and make it difficult for the participant to move and to perform some manual tasks (e.g. respiration sensor, blood volume pulse sensor)

For the use of the FlexComp Infiniti unit, the following aspects must be taken into consideration:

- Researchers must be careful with the leads to make sure they are attached to the participant body.

- In the case in which sensors are difficult to attach, one possible solution is to attach the sensor to the electrode prior to adhering the electrode to the participant.
- For the case of bulky sensors, researchers must assure that the experiment in question does not require the participant to perform actions that would be affected by the presence of the sensors, or at least, should take these actions into consideration when analysing the results.

3.4.7.4 Application of the Acquired Units

Both the FlexComp Infiniti and the B-Alert system have great research potential and are robust systems that would allow researchers to conduct a vast array of experiments. Both systems include detailed instructions on how to assemble and disassemble the units, set-up the sensors and run the measurements. All these instructions are included within the user manuals shipped with the units.

These selected units, as long as applied to the right projects (considering assembly and disassembly times, bulkiness of the units, participant discomfort), have a great research potential and can be used in various research settings such as:

1. Learning studies

2. Arousal studies

3. Vigilance studies

4. Interface design

5. UAV performance studies

The B-Alert System and the FlexComp Infiniti are flexible and easily adaptable units that could work in integration with other technologies in the GCS UAV research and control environment. These units could be used for evaluations of interface designs and as input to adaptive automation systems. For both cases the acquired EEG and ECG technologies will support the researchers in the development of the multimodal GCS interface..

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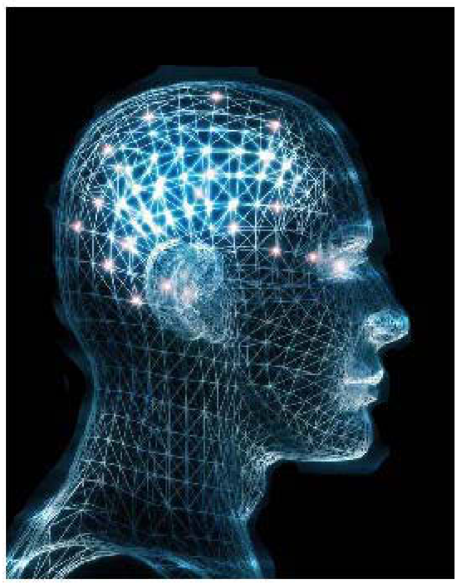
Annex A B-Alert Wireless Headset Technology Review

EEG Technology Review:

Wireless Sensor Headset

B-Alert® Software

Alertness and Memory Profiler (AMP)



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Description of the EEG Technology

The patented Wireless Sensor Headset provides an easy to administer platform for acquiring high quality electroencephalographic (EEG) and electrooculographic (EOG) signals and EKG. The sensor headset can be easily applied and comfortably worn for over 12 hours of continuous use. The patented EEG sensor dispenses a small amount of conductive cream through the hair to make electrical contact, which eliminates the need for hair or scalp preparation. The design of the analog circuit combined with EEG amplification close to the sensors and on-line impedance monitoring ensures that high-quality EEG data are obtained even by individuals with limited technical expertise. Wireless EEG allows the user freedom to move without generating artifacts obtained with conventional wired EEG systems.

Patented Wireless Sensor Headset: a. Side view. b. Rear view. c. Patented EEG sensor.

The B-Alert Software® applies patented signal processing procedures to identify and decontaminate artifacts that could result in incorrect interpretation of the EEG signals. The software monitors the level of artifact contamination to notify the user of data quality problems. The B-Alert software provides the capability to classify the brain's electrical activity into validated measures of engagement, workload, and distraction/drowsiness. These classifications are visually presented on a second-by-second basis and can be summarized across a recording session. The software includes event markers and provides multiple means to synchronize data from third-party software used for simultaneous recordings.

The Alertness and Memory Profiler (AMP) combines the Wireless Sensor Headset with a neurocognitive battery of vigilance, engagement, learning, and memory tests to simultaneously acquire and synchronize data on brain function and performance. The testing battery is customizable and employs an extensive selection of neurobehavioral tasks that can evaluate working and recognition memory using verbal and visuospatial tasks. Researchers are afforded a high degree of flexibility in selecting which tasks to include in their assessment. Neurocognitive constructs evaluated by the AMP include sustained engagement, processing speed, and verbal and visuospatial memory. When the AMP is administered in an office or workstation, the user is given a short training session before each task, and may call a technician if a problem is encountered to maximize ease of use. Additionally, AMP results can be compared to Advanced Brain Monitoring's normative database to assess neurocognitive impairment.

Unique Features of the EEG Technology

Wireless Sensor Headset

• The Wireless Sensor Headset provides the flexibility to acquire up to nine channels of physiological signals. Wireless acquisition provides the user the freedom to operate up to 30 feet from a workstation, laptop, or PDA. Bluetooth protocols allow multiple Sensor Headsets to operate in the same vicinity without interference.

• The Sensor Headset allows high-quality EEG to be acquired with no scalp preparation. The software automatically measures the level of impedance at each sensor, and notifies the user if a sensor requires adjustment.

• The Sensor Headset is economical to use. The foam that comes in contact with the hair/scalp is the only disposable component that must be replaced after each use. The sensors can be washed and reused up to 30 times.

• The Sensor Headset can be powered for over 7 hours with two AAA batteries. The battery voltage is monitored continuously and the user notified prior to expiration of the batteries.

• The gain and dynamic range is sufficient to acquire either elecrtroecephalography (EEG) or electrooculography (EOG). The Midline Sensor Headset is available in small, medium and large sizes and positions three sensors in the frontal (Fz), central (Cz) and parietal/occipital (PzOz) within 1 cm of the 10-20 system.

• Optional set-ups are available that provide a dynamic range sufficient for EKG. The Midline Sensor Headset is configured to acquire the bipolar signals needed to quantify engagement and drowsiness. It can also be configured to additionally acquire monopolar recordings from the midline sensors and/or EOG electrodes with linked mastoids, and EOG or EKG.

• The Sensor Headset used for Advanced Brain Monitoring's quantification of workload, engagement, and distraction/ drowsiness acquires six fixed bipolar channels using sensors at the midline plus lateral sites.

• The workload configuration places electrodes at F3, F4, Fz, C3, C4, Cz and POz within 1 cm of the 10-20 system. This configuration can be modified to acquire one channel of EKG in addition to five differential EEG channels necessary for workload

• The Sensor Headset can be customized to locate sensors according to the customer's specifications with defined combinations of monopolar or bipolar recordings from each sensor.

• The software provides a flexible graphical interface for viewing and analyzing physiological EEG signals. The amplitude of the signal presentation can be readily adjusted with features provided to scroll through the entire session.

• EEG artifact can be automatically identified and/or removed from the raw EEG signal in real time and monitored during acquisition.

• Continuous monitoring of artifact automatically alerts the user when poor-quality data thresholds are exceeded.

• The brain's electrical activity is transformed into measurements of workload, engagement, and distraction/drowsiness that can be monitored in real time or analyzed post hoc.

• Three baseline tasks, which take approximately 30 minutes total to perform, are used to fit the engagement and distraction/drowsiness algorithms to the individual's EEG characteristics.

• EEG data acquired from the primary data acquisition computer can be presented to a second computer with a TCP/IP network protocol, allowing real-time visual monitoring of EEG at alternative locations.

• Output files including EEG indices (i.e. power spectral density [PSD] calculations), levels of artifact, and brain state classifications can be generated for statistical analysis.

• Previously acquired EEG can be monitored in play-back mode, allowing the EEG to be simultaneously inspected with video recordings.

• The software provides multiple means to synchronize the EEG with task events/performance provided by third-party software.

Alertness and Memory Profiler

• The Alertness and Memory Profiler (AMP) consists of a battery of 12 neurocognitive assessment tasks to measure constructs of sustained engagement, processing speed, and verbal and visuospatial memory.

• The AMP provides an integrated recording of the simultaneously acquired EEG and performance measures. The presentation time of each stimulus, point of response, and response type are marked and available for real time or offline visual inspection.

• The AMP protocols can be customized to the user's needs, including which tasks are included, the order of the tasks, and the duration of each task. Between tasks, breaks can be inserted with notification provided to the subject when the study should resume. Behavioral measures of stress, mood and fatigue can be interspersed among the tasks using computer-based visual analog scales.

• The AMP presents verbal instructions to the user for each task. Practice periods are used to ensure the subject is trained to criterion on each task prior to starting data acquisition.

• The AMP will automatically notify a technician when problems require their engagement, thus minimizing technician involvement and the level of experience needed to administer the AMP.

Applications for the EEG Technology

The EEG Systems are currently being used in the following applications:

• Sustained engagement/fatigue management

• Error prediction and reduction

• Disease assessment and treatment monitoring

• Training optimization

• Ergonomic and design assessments

• Monitoring of group dynamics

Future applications include:

• Neurofeedback

• Lie detection

• Computer interfaces for the disabled

• Information management

• Pharmaceutical evaluations

Clinical Study Review of the EEG Technology

Advanced Brain Monitoring has studied over 800 subjects in the development and validation of the EEG and AMP systems. Results of the clinical studies that have been published in scientific journals are compiled in Appendices. The results below highlight the significant findings in these clinical studies.

• The EEG indices of drowsiness correctly classified 97% of the micro-sleep events scored by consensus between two Sleep Technicians and a confirmed behavioral measure (Finger Tapping). 1

• The mean correct classification of each second during micro-sleep was 86.0% while the mean correct classification of awake was 94.3%. The overall correct classification of sleep and awake was 92.7%. 1

• The mean canonical correlation between EEG indices of drowsiness and performance during a vigilance task across 44-hours of sleep deprivation was 0.889. The mean canonical correlation between EEG indices of drowsiness and technician observations based on video recordings and EEG tracings was 0.904. 1

• During the 44-hour sleep deprivation study, distinct patterns in the EEG and performance measures were associated with different levels of vulnerability to sleep deprivation, suggesting that objective measures can provide a “biobehavioral assay” to identify individuals most susceptible to sleep deprivation. 1

• During extended sleep deprivation, feedback alarms that were triggered by EEG indices proved effective in either stabilizing or improving alertness as measured by EEG indices and performance. This suggests that an EEG system with intelligent feedback can improve performance and decrease errors resulting from fatigue. 2

• A significant decrease in drowsiness as determined by EEG indices was observed in periods when feedback alarms were provided as compared to periods without feedback alarms. 2

• The AMP measures showed that untreated sleep apnea patients were significantly drowsier compared to age- and gender-matched healthy controls and approached the normal range after three-months of CPAP treatment. 3, 4

• The AMP Composite Evaluation Score (ACES) accurately identified 195 fully rested healthy subjects and 197 untreated sleep apnea patients (mean RDI = 51.2, range 5 to 165) with a sensitivity of 0.88 and a specificity of 0.96. 4

• Across cognitive workload tasks, specific changes in EEG were identified that were reliably associated with levels of cognitive workload. 5

• Cognitive workload tasks confirmed that EEG indices are related to cognitive effort associated with task difficulty, and not to the number of sensory inputs or the amount of motor output required for different levels. 5

• The level of task expertise had a substantial impact on EEG indices, with overall high vigilance percentages decreasing dramatically as a result of training. 5

• Correlations between EEG indices of workload and performance measures in the Warship Commander Task were greater than 0.85 in the majority of participants. 5

• In a military command and control simulation environment (Aegis), the EEG workload indices identified periods of high/extreme EEG-workload during high cognitive-load tasks with a detection efficiency approaching 100% for the most difficult events. 6

• In the Aegis simulation environment, over 95% of high/extreme EEG workload across participants occurred during high-difficulty events (false positive rate <5%). The high/extreme workload occurred between 25 to 30% of the time. 6

• During a simple working memory task, the EEG system classified spatial versus verbal tasks with a classification accuracy of 77.0%. 7

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Sensor Headset Model 603-B Specifications

System Specifications - for Head and Host Units	
RF Band	2.4 to 2.48 GHz (ISM band)
Antenna	On-board
Transmission Mode	Bi-Directional
Data Transmission Range	~ 30 feet, line of sight
Average Data Loss	< 0.1%
Transmission Power	~ 1 mW
Power Supply	2 x AAA 900 mAH NiMH batteries
Operating Time	7.0 hours between charges
Power Consumption	~ 80 mA @ 2.5 V
Battery Charger	External, interface via Charging Jack
User Control	ON/OFF
Indicator LEDs	Green = in sync with head unit Red = device on but not in sync with Head Unit
Number of channels	3-9
Sampling Rate	256 samples/second
Dynamic range	$\pm$1,000 µV, sufficient for either EEG or EOG
Resolution	16 bit
Bandpass characteristics	0.5 Hz and 65Hz (at 3dB attenuation) obtained digitally with Sigma-Delta A/D converter
Noise	~ 2 µV peak to peak
On-line impedance monitoring	Initiated by host computer using bi-directional link
Connector Interface	12-pin Hi-Rose connector for Sensor Headset
Head Unit Dimensions	5" long x 2.25" wide x 1" deep
Head Unit Weight	4.0 ounces with batteries
Case Material	ABS
Blue Tooth Dongle Host Unit	Blue tooth Version 1.2, class 2 USB dongle
Software	
Compatibility	Personal computer with 1 MHz or higher processor 512 MB of RAM running Windows XP
Estimated File Size per Minute	~ 30 KB/Min/channel
Recharging Batteries on Head Unit	

Provided by zipling USB charger	350 mA @ 5 Volts
Recharging Cable	10" cable terminated a USB A connector and a HiRose connector on each end
Sensor Headset and accessories	
Headset and Sensor Strip	Medium = Nasium to Inion ~36 cm. From Inion: POz = 7.2 cm, Cz = 18 cm and Fz = 25.2 cm
Sensors	Silver-Silver Chloride coated ABS
Electrode Cream	Highly conductive, electrolytes and preservatives in non-ionic, hypo-allergic base, buffered to skin pH

Annex B g.MOBIlab+ Brochure

Mobile biosignal acquisition with Pocket PC or notebook / PC

g.MOBIlab+

MOBILE & WIRELESS BIOSIGNAL ACQUISITION

Highlights

- acquire EEG, ECG, EOG, EMG and other signals even outside your lab
- on-line visualization and storage of up to 16 channels on a Pocket PC or notebook / PC
- various software solutions available (driver/API, recording software, MATLAB/SIMULINK/LabVIEW ...)
- transmit online biosignal data wirelessly via Bluetooth 2.0 to a Pocket PC or notebook / PC
- log data directly on an internal flash card memory (Mini-SD card)
- integrate the device into your real-time system under SIMULINK (BCI, neuro-, biofeedback)

***g.MOBIlab*+** - g.tec's mobile and wireless biosignal acquisition system - is the perfect tool for recording multimodal biosignal data on a standard Pocket PC or notebook / PC . It allows to investigate brain-, heart-, muscle-activity, eye movements, respiration, galvanic skin response and other body signals. Various sensors and electrodes are available. Ask for complete packages or customized solutions!

The system is available as an 8-channel "EEG-version" and a "multi-purpose version" with 6 amplifier inputs (4 channels for EEG/EOG and 2 channels for ECG/EMG) and 2 analog input channels for external sensors. 8 digital channels can be used for trigger signals. The device is battery-supplied and designed for long-term operation. 16-Bit technology and 256 Hz sampling rate guarantee high-quality biosignal recordings.

Technical details and specifications

g.MOBIlab+ (8-channel EEG version)	EEG Channels: 8, Filters: 0.5 - 100 Hz, Sensitivity: 500 µV (monopolar), no additional analog inputs		
g.MOBIlab+ (multi-purpose version)	EEG Channels: 2 Filters: 0.5 - 100 Hz Sensitivity: 500 µV (bipolar)	EEG/EOG Channels: 2 Filters: 0.01 - 100 Hz Sensitivity: 2 mV (bipolar)	ECG/EMG Channels: 2 Filters: 0.5 - 100 Hz Sensitivity: 5mV (bipolar)
Analog inputs (multi-purpose)	Channels: 2, Filters: DC-100 Hz, Sensitivity: +/- 250 mV (monopolar)		
Additional inputs/outputs	4 digital inputs/outputs, 4 digital inputs (TTL), +5V		
Power supply	4 standard AA batteries or accumulators (25 - 100 hours operation time, depending on mode)		
Data acquisition	ADC with 16 Bit and 256 Hz/channel, serial interface (RS232), Bluetooth 2.0 / class I (+)		
Standard	Manufactured according to IEC 60601-1, for research application, no medical device		
Internal storage card	Micro-SD flash memory card (up to 2 GB), accessible via the battery compartment		
Weight	360 gram (including batteries)		
Dimension	155 mm x 100 mm x 40 mm		

8-channel EEG version

multi-purpose version

g.tec is an official MATLAB partner. (The MathWorks, Inc., Natick, MA)

MATLAB® and SIMULINK® are registered trademarks of the MathWorks Inc.

g.MOBIlab+

Get rid of the cable ...

Bluetooth 2.0 technology enables a wireless online-transmission of biosignal data to the Pocket PC or notebook/PC with g.MOBIlab+.

Transmission works well for distances of 30 meters (indoor) and up to 200 meters (outdoor).

Sensors for g.MOBIlab+:
GSR, pulse, respiration, snoring sensor, temperature sensor, ...
Ask for more sensors!

Log data ...

An integrated flash memory (Micro-SD card) enables data logging even after the device is disconnected from the computer.

With up to 2 GB space on the flash card a total recording time of 120 hours is provided.

Start quickly ...

The easy handling of hardware and software combined with highest signal quality makes the g.MOBIlab+ a favoured tool for scientists, teachers and system developers.

A large variety of available accessories and sensors enable the user to investigate even unusual scientific questions.

Good connections ...

Various connector boxes for the different versions of the device assure a safe and easy connection of electrodes and sensors.

Shielded cables reduce artifacts. Touch-proof safety connectors are the standard. Ask for customized connectors and adapters if required!

Colorful solutions ...

For ECG and EMG recordings a patient cable for use with adhesive disposal Ag/AgCl electrodes is provided.

Acquire biosignals reliably even in sportsmen, vehicle drivers, pilots or small children.

Perfect timing ...

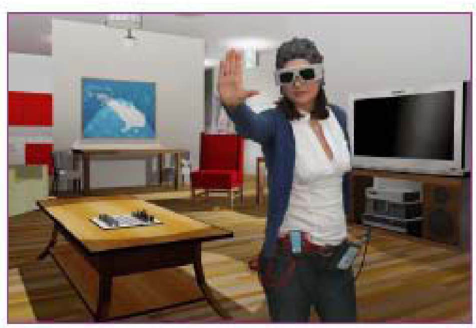
With up to 8 digital I/O signals even tricky experimental paradigms can be realized. All triggers are recorded synchronously with the biosignals.

Simple pushbuttons allow the subject to respond to experimental stimulation or to mark events during recording.

Look up our website or contact us at any time to find out more about available software solutions and how to use g.MOBIlab+ in MATLAB/SIMULINK or LabVIEW!

8-channel active EEG system

Instead of the standard EEG electrode connector box g.tec's active electrode system "g.GAMMAsys" can be used. No skin preparation and no abrasive gel is required any longer. High quality EEG recording with a fully wearable active system!



Application example: Navigation in the virtual reality with a BCI

A Brain-Computer Interface (BCI) is used to navigate in a VR environment and to control simulated installations. EEG data are sent wirelessly to the computer so the subject can freely move around. See also g.tec's virtual reality system "g.VRsys"!

g.tec

Annex C Biosemi ActiveTwo Brochure

MindWare TECHNOLOGIES LTD.

Print

BioSemi
Model 62-9007-00

Product Description

Multi-modal data acquisition system with active electrodes

ActiveTwo is a powerful new high-resolution biosignal acquisition system that incorporates some revolutionary concepts. Active electrode technology is just one of the significant innovations in the ActiveTwo system. By placing active electronics within millimeters of the actual electrode contact, ActiveTwo virtually eliminates the need to prepare the scalp before applying electrodes. This can cut measurement preparation time by an estimated 15-30 minutes for most laboratories!

ActiveTwo can also be equipped with additional sensors for respiration, skin conductance, temperature, plethysmograph (pulse) and other parameters. An optional isolated analog input box makes it possible to acquire almost any type of signal synchronously with the signals sampled by the ActiveTwo A/D box.

As an added benefit, ActiveTwo comes with powerful data acquisition software developed in National Instruments' LabView. We provide the compiled software so you do not need to own LabView, and you do not need to be a programmer to operate the system. For those laboratories with programming resources, the source code is provided so that you can add any special features that you may need.

New Features of ActiveTwo

- Optional optically isolated auxiliary signal input box for simultaneous acquisition from unisolated signal sources or for acquisition from multiple patients at the same time
- Synchronized 24-bit sampling, no skew, zero-reference principle
- Sigma-Delta converter technology offers > 100 dB dynamic range, guaranteed no missing codes, and less than 10 ppm integral non-linearity
- Fully DC coupled operation in all modes, +/-262 mV input range, no high-pass filtering in hardware
- Adjustable sample rate: 2, 4, 8 or 16 kHz sample rate per channel (throughput is 1.5 MB per second)
- Up to 280 channels in an integrated front-end
- Synchronous acquisition from multiple subjects with perfect electrical isolation on a single host computer.

Key Benefits

- Fast application time without skin preparation
- Reliable measurements due to low-noise design
- LabView acquisition software comes with source code so you can implement changes as you see fit
- Low cost! Cost-per-channel actually decreases as the number of channels increases
- Number of channels can be upgraded easily, up to 280
- Compact front-end is battery powered for improved data quality
- Only system on the market with active electrodes
- Only 24-bit biopotential measurement system on the market with this collection of features
- DC amplifier with the largest input range. This is the first DC amplifier with an input range like that we have come to appreciate in typical AC designs. The ActiveTwo simply will not saturate on difficult electrodes
- Only system with 280 channels in an integrated design, no coupling of sections / boxes with its inevitable increase of interference and reliability problems

- Only battery-powered, fiber-coupled system with more than 64 channels
- Highest sustained data throughput. 1.5 MB/s of raw data is processed by the PC. All this data can be stored to file without any data-reduction if required
- Only system with completely open (LabVIEW) software environment.

Contact Information

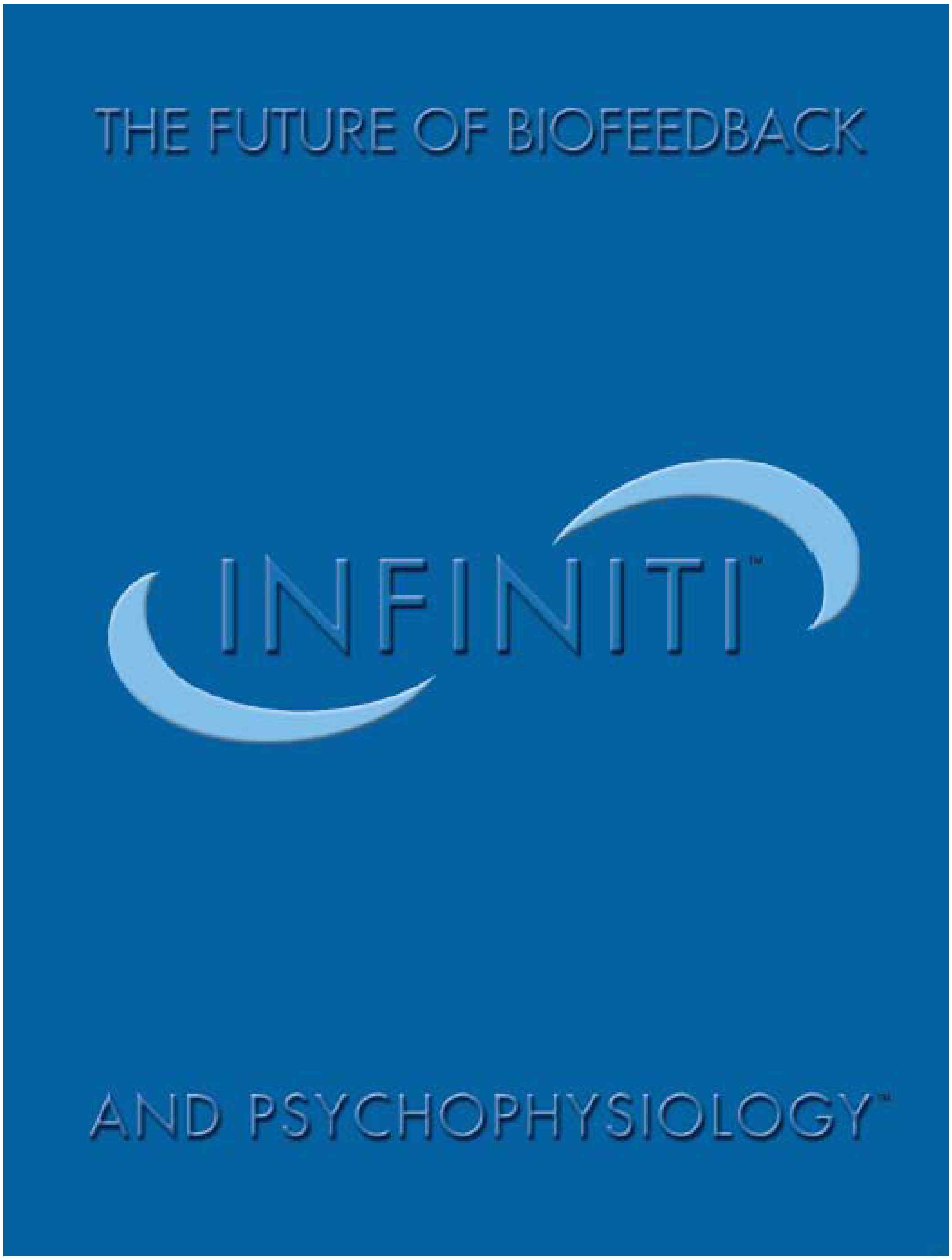
Mindware Technologies LTD

1020F Taylor Station Rd.
Gahanna, OH 43230

Phone: (614) 626-4888
Fax: (614) 626-4915
Toll Free: (888) 765-9735 (US Only)

info@mindwaretech.com

Annex D FlexComp Infiniti Brochure



Full Compatibility

Current users of Thought Technology products can rest assured that the new Infiniti Technology Platform will work perfectly with their existing hardware or software. For example, the new ProComp Infiniti encoder device is completely compatible with existing BioGraph® software, while ProComp+™ users will find that their ProComp+ performs seamlessly with the new BioGraph Infiniti Legacy software suite.

Of course, using the new ProComp Infiniti hardware together with BioGraph Infiniti software allows you to take full advantage of all our new features and enhancements.[1]

- High sampling rates enable you to record RAW signals even at high frequencies
- Automatic sensor recognition to ensure proper setup each time
- Low battery warning prevents you from losing important data
- Feather-light fiber optic cable for noise-free real-time monitoring
- User triggered auto re-calibration for sustained accuracy between environments
- Integrated impedance checking for enhanced quality of recording in one easy step

Infiniti Hardware Platform

Our new ProComp Infiniti and FlexComp Infiniti encoder devices incorporate cutting-edge technology, while enhancing the signal quality, resolution and integrity that made earlier generations of Thought Technology hardware synonymous with quality and reliability.

FlexComp Infiniti, our top-of-the-line encoder, is the ideal data acquisition and psycho-physiological monitoring device for power users. It offers ten high-speed channels (2048 samples/sec.) that can acquire data from any Thought Technology sensor.

Researchers and clinicians will appreciate its flexibility to display raw, median frequency, RMS, peak-to-peak, 2D and 3D frequency and power spectrum, sEMG, EEG and EKG signals. Up to four encoders can be connected together to produce a forty-channel "window" into a subject's physiology.

From the lab to the field, FlexComp Infiniti has the power to record and save complex data instantaneously to the computer or Compact Flash (for remote data storage).

The Infiniti Software Technology Platform features:

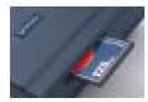
- Powerful data-acquisition
- Cutting-edge multimedia biofeedback
- A library of application-specific Clinical Suites
- Clinical tools for assessment and training
- Extensive data review and analysis functions
- Personalized session reports
- Enhanced trend reporting on client progress
- Full screen channel and script editors when using the Application Developer Suite

The ProComp Infiniti is an eight-channel, multi-modality encoder that has all the power and flexibility you need for real-time, computerized biofeedback and data acquisition in any clinical setting.

ProComp INFINITI

Housed in an ergonomically-designed case and requiring only a USB port, ProComp Infiniti can be used with any IBM-compatible laptop or desktop PC. The new high-speed TT-USB connection allows for higher sampling rates. The first two sensor channels provide ultimate signal fidelity (2048 samples per second) for viewing raw EEG, EMG and EKG signals. The remaining six channels (256 samples/sec) can be used with any combination of sensors, including EEG, EKG, RMS EMG, skin conductance, heart rate, blood volume pulse, respiration, goniometry, force, accelerometers*, torsiometer* and voltage isolator.

What's more, not only can ProComp Infiniti capture data in real time by connecting directly to the PC via its fiber-optic cable, but it can also store data on a Compact Flash memory card for uploading later to the PC.



In short, ProComp Infiniti covers the full range of objective physiological signals used in clinical observation and biofeedback in any environment.

ProComp Infiniti can capture data in real time by connecting directly to the PC via fiber-optic cable.

The ProComp2™ is a compact yet powerful two-channel device that allows clinicians to set up a second clinical system – or to empower their clients by offering them a take-home device that is convenient to wear on a headband or a shirt collar.

The ProComp2 contains a built-in EEG sensor (simply connect an extender cable for EEG monitoring and biofeedback), and it can use any two of the ProComp Infiniti sensors. The ProComp2 system contains all the peripherals to easily connect it to a desktop or laptop IBM-compatible PC.

Benefits for you and your clients

- Ability to expand your clinical practice quickly and economically by adding training rooms
- Power to train in home environment, thereby enhancing long-term compliance and improved outcomes
- Capacity to monitor peripheral measures as well as EEG for greater flexibility

Complete Range of Sensors

Skin Conductance
Measures the conductance across the skin, normally connected to the fingers or toes. Supplied with two finger bands.

Temperature Sensor
Small bead thermistor measures temperature from 50 - 115 °F/ 10 - 45 °C with >0.008 °F resolution.

Respiration
Electronic sensor with Velcro belt for monitoring respiration rate, amplitude and rate.

Blood Volume Pulse (BVP)
Finger-worn photoplethysmograph displays the pulse waveform, and measures amplitude and heart rate.

Pre-amplified EMG, EEG and EKG sensors
amplifies the signals at the measurement site, and can detect signals as small as 0.10 microVolts. Low noise wire and gold-plated protected-pin connectors ensure unparalleled accuracy, even when moved.

Thought Technology's advanced design and active electronic sensors meet exacting standards for instrument accuracy, sensitivity, durability, and ease of use.

All sensors are completely non-invasive and require little or no preparation for use.

After-Sales Service

- A one-year warranty policy (optional three years) on all encoders and sensors provides peace of mind.
- Training courses at various skill levels help you maximize the use of your system.
- Our professional and friendly technical support staff makes getting assistance stress-free.
- Prompt and reliable service gives you what you are looking for when you buy the best.

Specifications

	FlexComp Infiniti (SA7550)	ProComp Infiniti (SA7500)	ProComp2 (SA7400)
Size	5.1" x 3.7" x 1.5" (130 mm x 95 mm x 37 mm)	5.1" x 3.7" x 1.5" (130 mm x 95 mm x 37 mm)	2.7" x 2.8" x 0.75" (65 mm x 71 mm x 19 mm)
Connection to PC	Fiber Optic to USB through TT-USB interface unit	Fiber Optic to USB through TT-USB interface unit	Fiber Optic to USB (TT-USB) or COM port (Pro-SB)
Sensor type	External sensors	External sensors	Internal EEG or any 2 External sensors
Impedance checking (with EEG-Z sensor)	All channels	All channels	Channel B only
Self-calibration	Yes	Yes	No
Compact Flash memory storage	Yes	Yes	No
Fast channels (rate, bandwidth)	10 channels, 2048 samples/sec, DC – 512 Hz	2 channels, 2048 samples/sec, DC – 512 Hz	2 channels 256 samples/sec DC - 45 Hz (shared with slow channels)
Slow channels (rate, bandwidth)	Emulated protocols only	6 channels, 256 samples/sec, DC - 64 Hz	2 channels 32 samples/sec, DC - 8 Hz (shared with fast channels)
Emulated protocols	ProComp Infiniti, ProComp+	ProComp+	ProComp+ (2 channels active)
Power source	4AA batteries, single-use alkaline or NiMH rechargeable	4AA batteries, single-use alkaline or NiMH rechargeable	1 AA battery, single-use alkaline
Battery life (alkaline cells)	30 hours typical, 20 hours minimum	30 hours typical, 20 hours minimum	10 hours typical
ADC output	14 bits	14 bits	13 bits

[1] See our software brochure for more information. This brochure describes the encoders in their Infiniti modes not Legacy settings.
[2] Contact Thought Technology or your local representative for availability.

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www.thoughttechnology.com

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THE INFINITI

Thought Technology systems are recognized as the standard of excellence by clinicians, therapists and researchers throughout the world. We are committed to design and manufacture physiological monitoring and biofeedback instruments that are precise and reliable – for both computer-based and stand-alone applications. Our vision is to expand the exciting potential of behavioral,

TECHNOLOGY

psychophysiological and non-invasive medicine in the 21st century, so that we may further enhance human health and self-efficacy. The Infiniti Technology Platform incorporates the latest advances in hardware and software architecture. Its modular design offers maximum flexibility and ease of use across a wide range of applications.

PLATFORM

Annex E g.USBamp Brochure

EEG/ECoG/ECG/EMG/EOG/... high performance biosignal acquisition

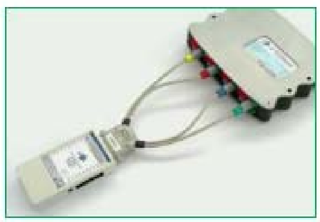
g.® USBamp generation 3.0

USB BIOSIGNAL AMPLIFIER

Highlights

- real DC-coupled EEG/ECoG/ECG/EMG/EOG biosignal amplifier with wide-range inputs
- 24-bit high resolution ADCs, up to 38.4 kHz sampling with simultaneous S&H for all channels
- internal floating point DSP for digital preprocessing and signal filtering
- 16 input channels per unit, units can be stacked to set up multi-channel systems
- internal amplifier calibration and automatic electrode impedance check
- 4 independent ground potentials per unit to avoid interference between different signal types
- various software solutions available (driver/API, recording software, MATLAB/SIMULINK/LabVIEW ...)
- CE and FDA certified medical device for non-invasive and invasive recordings
- USB 2.0 interface

Multiple units of g.USBamp can be stacked to set up a multi-channel system. All channels are sampled synchronously.



g.USBamp works with any type of passive electrodes and strip or grid ECoG electrodes. The g.GAMMAsys active electrode system can be used as well. Single cell recordings can be performed in combination with g.tec's spike sensor system.

g.USBamp can be used with a medical power supply or with a rechargable battery pack for up to 10 hours of independent operation.

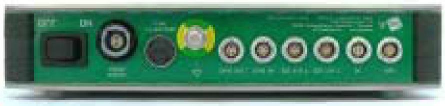
MathWorks Partner

g.tec is an official MATLAB partner. (The MathWorks, Inc., Natick, MA.)

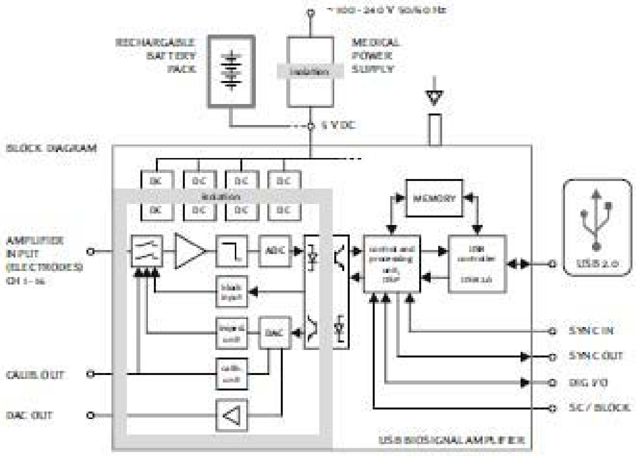
MATLAB® and SIMULINK® are registered trademarks of the MathWorks Inc.

certified medical device notified body CE 0636

FDA medical device clearance k060803



rear side view



g.USBamp

USB BIOSIGNAL AMPLIFIER

Sensitivity:	< 30 nV (LSB) - ± 250 mV
Amplifier type:	real DC coupled
16 x ADC:	24 bit (38.4 kHz internal sampling per channel)
2 x DAC:	12 bit
Input channels:	16 mono- / 8 bi-polar (per device, software-selectable)
Noise level:	< 0.3 µV RMS (0.1 - 10 Hz)
Input impedance:	> 100 MOhm
Input connectors:	standard safety connectors and system connectors
Weight:	1000 g
Size:	197 x 155 x 40 mm
Applied part:	type CF
Safety class:	II
Directive of medical products:	93/42/EWG
Standards:	EN60601-1: 1996 (+A1 +A2 +A12 +A13) EN60601-2-26: 2004 EN60601-1-2: 2003 EN60601-2-25 +A1: 2001 EN60601-2-40: 1998

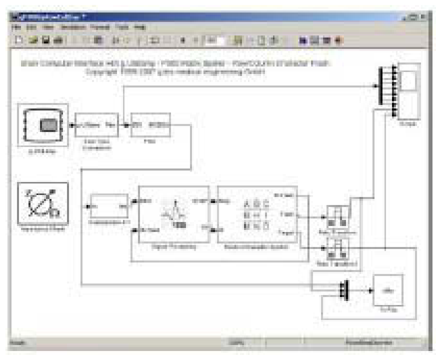
g.USBamp is equipped with 8 TTL-trigger inputs which are sampled synchronously with all input channels. Also additional digital I/Os are accessable via a rear-side socket. The SC (short cut) input allows to disconnect the electrode sockets from the amplifiers during electrical or magnetical stimulation in order to reduce artifacts.

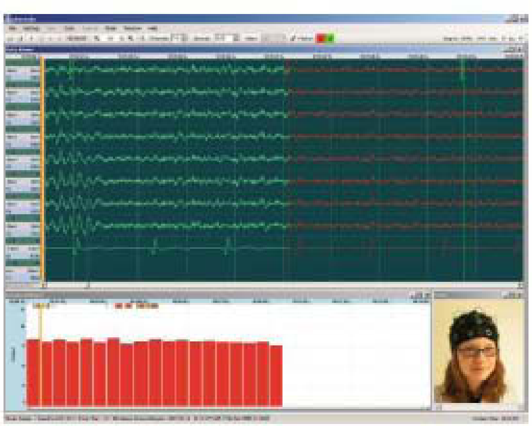
Software options:

API/device driver:
This option enables the integration of the hardware into an existing data recording or processing system by the user or to program applications in C++ or other Windows-based programming languages. *g.USBamp* is also supported by BCI 2000.

The MATLAB API:
With the MATLAB API the MATLAB Data Acquisition Toolbox can be used to get full access to the recording buffer and to use the whole functionality of *g.USBamp*. The Data Acquisition Toolbox enables a quick and easy implementation of data visualization, processing and storage applications under MATLAB.

High Speed Online Processing for SIMULINK (or LabVIEW):
Online/real-time biosignal processing and recording with the maximum system speed! *g.USBamp* appears as a block usable in any SIMULINK model. The design of the hardware-interrupt controlled driver allows immediate starting of the model without prior compilation. Also g.tec's specialized *g.RTanalyze* blockset can be used for real-time parameter extraction and data classification. The example shows a BCI system (P300-spelling device) with *g.USBamp* realized in a SIMULINK model.





g.Recorder:
Our recording software supports all data acquisition devices provided by g.tec. Comfortable system configuration, data visualization and storage make *g.Recorder* a perfect tool for teaching, research and clinical investigation. *g.Recorder* also supports video-EEG and online biosignal parameter monitoring.

For offline biosignal analysis please see *g.BSanalyze*. This software package includes powerful toolboxes for EEG analysis, high-resolution EEG, ECG (heart rate and HRV analysis) and single beat ECG analysis as well as for biosignal classification.

Annex F I-330 C2plus 12 channel Brochure

I-330-C2 Plus Clinical System - 12 Channel

JJE I330C2
Price: $3,170.00
Free Shipping to US & Canada

The I-330 C2 monitors and records up to 12 channels of physiological activity - 4 available for sEMG/EEG or ECG with the remaining channels dedicated to temperature, heart rate, respiration and skin resistance.

Features

The J&J I-330-C2 Plus has 12 channel capability that supports simultaneous monitoring of signals, such as:

- Two person monitoring for ECG, HRV, Respiration, and Skin Resistance or Conductance
- 4 available EMG channels with spectral and raw signal displays, two Skin Resistance and Conductance, two Temperature
- ECG, EMG, two Respiration, Skin Resistance, Temperature
- Two EEG channels, Respiration, Skin Resistance, Temperature

About the I-330-C2 Plus Clinical System - 12 Channel

The popular J&J I-330-C2 Plus has advanced Windows based software and a fast USB interface. It has 4 differential channels allocated for sEMG, ECG, EEG, and 8 channels allocated for temperature, skin resistance, and respiration provide power, flexibility and functionality for a multitude of customized uses.

J&J Engineering's software displays signals, provides feedback, collects data, prints reports, and exports database compatible files. Features include automatic testing of electrode impedance for connection quality, easy hookup with reusable gel free sensors, and fast channel sampling at 1024 samples per second for high resolution spectral displays and precision filtering.

Connects via USB to laptop or desktop running Windows 98 or later release.

Completely software driven to provide feedback graphics, games and audio. Self test features display impedance, power and noise levels.

The I-330 C2+ software is fully compatible with Microsoft Windows98, WindowsNT, Windows2000, WindowsME, WindowsXP or Vista and has been designed with the needs of the clinician as well as the researcher in mind.

Includes

- I-330 C2 Plus module with **USB** connection
- USE-3 Software
- (1) MC-5SGW EMG/EEG/ECG Cable with ground
- (1) MC-5SW EMG/EEG/ECG Cable
- (1) MC-6SY Temp/EDR Sensor Cable
- (2) SE-35 Velcro EDR Snap-on-style Finger Sensors
- (1) SE-15 Adhesive Pads with AgAgCL snap pellets
- (1) JE-24 Conductive Cream
- (4) AA batteries
- Users manual

Specifications

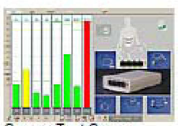
- Input Channels: (4) sEMG,ECG,EEG and (8) Skin Resistance, Heart Rate, Temperature, Respiration.
- Input Ranges: ±100 µV, ±500 µV, ±2000 µV
- Input Impedance: 10 Gohm,
- Notch Filter: 50/60 Hz
- Maximum Bandpass: 1 to 400 Hz
- Max sample rate/channel: 1024 SPS
- EMG Bandpass: 100Hz to 400Hz, 20Hz to 400Hz
- EEG Bandpass: 1 to 50Hz
- EEG Artifact Detector: 30Hz to 100Hz RMS
- Heart Rate Bandpass: 1Hz to 400Hz
- R Wave Filter & Detector: Single Beat Update
- IBI or HR Output: 40 to 200 beats/minute
- Temperature Range: 60° to 100°F (15° to 38°C)
- Skin Conductance Range: 1 to 100 µS
- Electrode Impedance Test: 250 Ohm to 1 Mohm
- I/O Format: USB or RS232*
- Isolation, Optical: 4000VAC
- Amp Failure Protection: 50 µA maximum
- Static Discharge Protection: +15,000V
- Power Source: (4) AA alkaline batteries

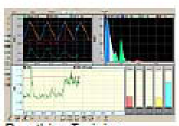
Computer Requirements

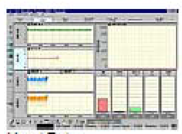
Recommended computer speed of 1 GHz. However, the need for processor speed is screen specific. If you don't mind slower performance on the processor hungry spectral display screens, the Windows software and C2+ should run on slower systems, too.

If you want to use dual monitor features, a faster machine (over 2GHz) is recommended.

The I-330 C2+ software is fully compatible with Microsoft Windows98, WindowsNT, Windows2000, WindowsME, WindowsXP or Vista.


Sensor Test Screen


Breathing Training Screen


Heart Rate, Respiration, Heart Variability Bands

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(U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Plinio Morita; Fiona Chui; Catherine Burns

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August 2010	69	

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(U) To improve operational effectiveness for the Canadian Forces (CF), the Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System (JUSTAS) project is acquiring a medium−altitude, long−endurance (MALE) uninhabited aerial vehicle (UAV). In support of the JUSTAS project, Defence Research and Development Canada (DRDC) – Toronto is investigating strategies for managing massive information exchange among UAV operators. One strategy to is to develop intelligent adaptive interfaces (IAI) that dynamically manage information display and control characteristics based on operator mental state or workload through assessing operators' physiological indexes by using Electroencephalography (EEG) and Electrocardiography (ECG) technologies. This report presents research findings in evaluating EEG and ECG technologies, lessons learned on the use of these technologies, and their associated implications in experimental research. Suggestions are made for the development of a research program for a study to enhance the IAI design. Recommendations are also provided for defining future requirements in support of the JUSTAS project.

(U) En vue d'améliorer l'efficacité opérationnelle des Forces canadiennes (FC), l'acquisition d'un engin télépiloté (UAV) moyenne altitude et longue endurance (MALE) est un des volets du projet Système interarmées de surveillance et d'acquisition d'objectifs au moyen de véhicules aériens sans pilote (JUSTAS). À l'appui du projet JUSTAS, Recherche et développement pour la défense Canada (RDDC) — Toronto effectue des recherches sur des stratégies visant à gérer l'importante quantité d'information échangée entre les opérateurs d'UAV. L'une de ces stratégies consiste en la mise au point d'interfaces adaptatives intelligentes (IAI) qui gèrent l'affichage de l'information de façon dynamique et commandent les caractéristiques en fonction de l'état mental de l'opérateur ou de sa charge de travail mentale à partir de l'évaluation des indices physiologiques de l'opérateur au moyen de technologies d'électroencéphalographie (EEG) et d'électrocardiographie (ECG). Le présent rapport décrit les découvertes faites lors de l'évaluation de technologies d'EEG et d'ECG, les leçons retenues de l'utilisation de ces technologies et leurs répercussions sur la recherche expérimentale. Il comporte des suggestions relatives à l'élaboration d'un programme de recherches visant à améliorer la conception des IAI, et des recommandations en vue de cerner les exigences futures à l'appui du projet JUSTAS.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Uninhabited aerial vehicle; multimodal interface; psychophysiological technologies